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TOKYO · JAPAN

NOVEMBER 1960

# THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

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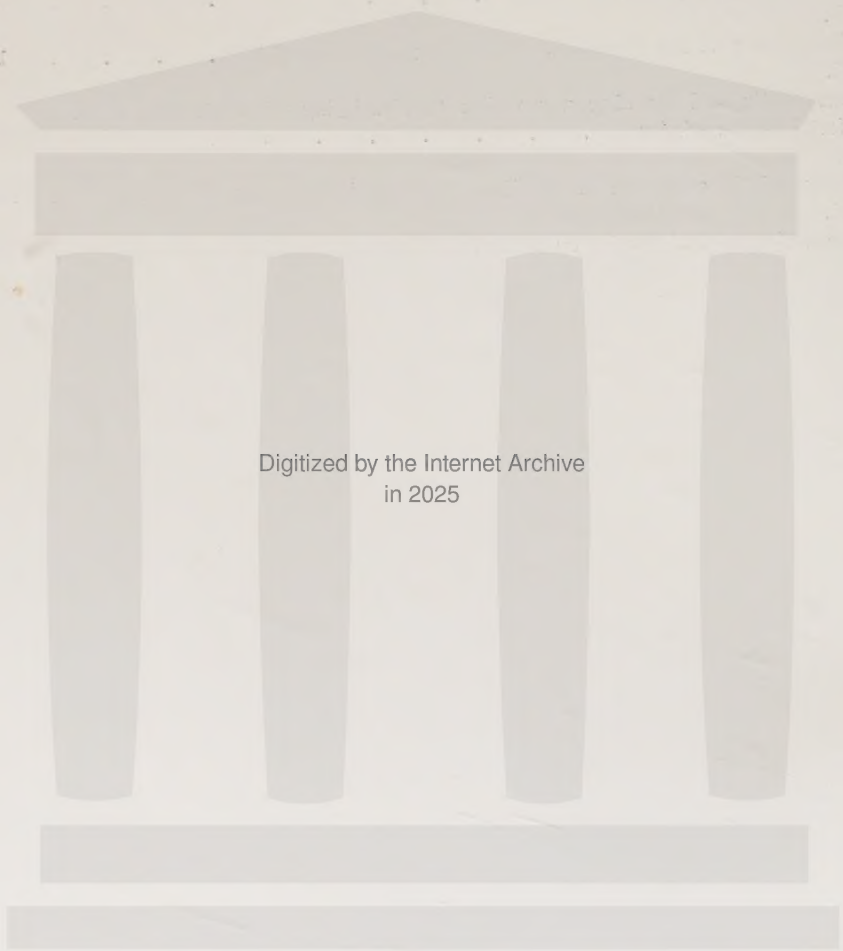

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# RYUKYUAN HUMPBACK WHALING IN 1960

MASAHARU NISHIWAKI

## INTRODUCTION

Accepting the invitation from the Government of Ryukyu Islands at the opening of the third Ryukyuan whaling since their regularization, the author had been engaged in the biological investigations about four months starting on December 16, 1959. Among this year's catches were 167 humpback whales, 14 sperm whales and one Bryde's whale. The author wishes to make a study of the humpback whale in this paper.

## METHOD OF INVESTIGATION

In the Antarctic and the Aleutian Expedition there are a great deal of catches and a short time available in dealing with each of them. Therefore, a close and exact investigation has not been made and we usually concentrate on a few necessary items with the accumulated data for ten and some years and make a good result. On the other hand in Ryukyuan waters where there are a less amount of catches and more time available for each of them, we have decided to make a similar close investigation to that of 1959 on the earnest proposal of the Government of Ryukyu Islands to develop fundamental methods in whale research.

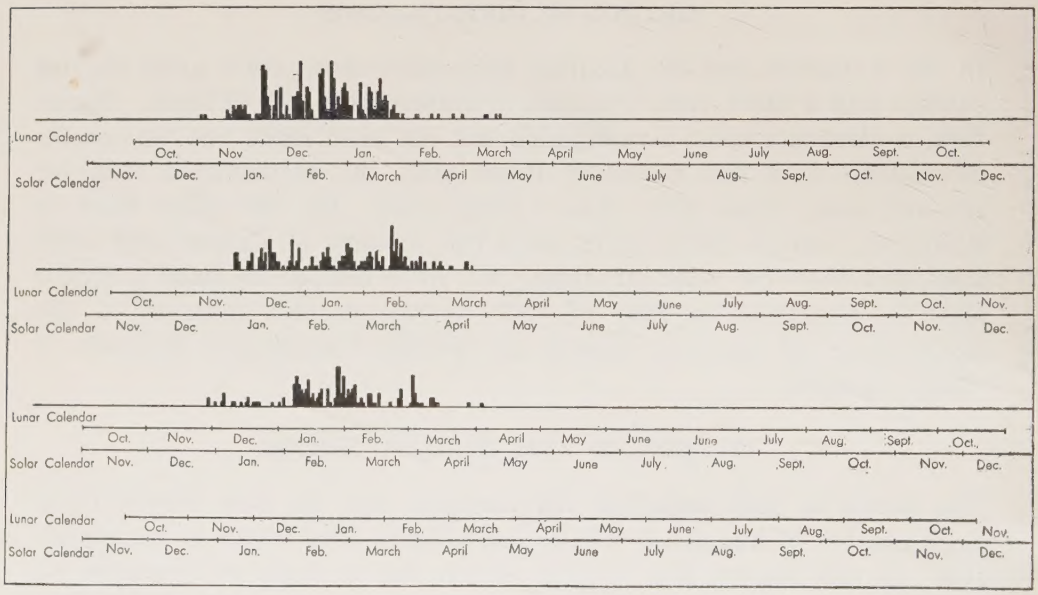
## OUTLINE OF THIS WHALING SEASON

The season in 1959 began on 7th January, but by that time a fairly arge number of humpback whales had already been found to be migrating. In this respect this whaling season was to begin on December 15, 1959. Though the whaling operation and scouting started on that day, we could get the first catch on 28th of December. The ships leaving Japan for Ryukyu in the beginning of December could find no whales before that time, and it was impossible to carry out the marking project. After 28th of Dec. we did not get the consecutive catches, and as Fig. 1 shows, we had only a few catches in December and January. Scouting was done with great effort and there was some anxiety that the humpback whales were already exhaustible.

While the humpback whaling was very dull, sperm whale scouting was done around the 20th January with the major tide. It is a matter for congratulation that a school of about 30 middle-sized sperm whales was

encountered and 14 of them were caught. In the following major tide, the author was requested to scout sperm whales, but it is to be regretted that active scouting was not done for the main purpose of catching humpback whales. A Bryde's whale was caught by chance on March 4, and we did not dare to scout the whale positively. It is, however, sincerely expected that the two species play an important part in the future Ryukyuan whaling.

In February the amount of catches rose favorably. It is not a rare phenomenon that the activity of marine animals is subject to the tidal and lunar rhythms. Reaching the conclusion that the whales, especially in case of coastal migration, must be subject to these changes, the author has shown the data of three-year catches applied to the lunar and solar calendars in Fig. 1.


Lunar Calendar
Oct. Nov Dec. Jan. Feb. March April May June July Aug. Sept. Oct.
Solar Calendar
Nov. Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.
Lunar Calendar
Oct. Nov. Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov.
Solar Calendar
Nov. Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.
Lunar Calendar
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Lunar Calendar
Oct. Nov. Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov.
Solar Calendar
Nov. Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.

Fig. 1. Daily catches according to lunar and solar calendar.

The season both in 1958 and 1959 was in full swing early in December according to the lunar calendar. The migration which comes round every twelve months is apt to occur earlier. It has something to do with water temperature and it must be regulated in nature, as there is a regulator in a leap year.

It is considered that there is some difference in the occurrence of migration period, and that whales come round just at a suitable temperature. The time of migration does not change by days, but by a month in relation with the major and neap tides.

In this way it is reasonable to think that the migration of main groups this year occurred not in the beginning of December, but in the beginning of January in the lunar calendar. The beginning of January in the lunar calendar referred to the beginning of February in the solar calendar.

The cause for the small amount of catches in that year is the scarce source of whales in the sea, as well as the disagreeable weather.

There were many windy days when the catcher boats could not find a blow as the sign of the appearance of a whale and therefore could not get any catches. This seems the main cause of the poor catch in the middle of February and also in the middle and at the end of March. The staying period of the main group was considered to be until the end of February in the lunar calendar, according to the two-year data, and so this year it was to be until the first decade of April. This year there ware comparatively some catches before 9th of April, but after that we could get nothing but two whales for 20 days between 10th and 29th of April.

## COMPOSITION OF CATCH

In Table 1 there is a classification of the body length and physical condition. The male whose testis on either side is about 2.0 kg in weight is defined as mature. The female whose ovary contains neither new nor old corpus luteums is defined as immature. Some of them whose Graafian follicle was more than 30 mm in diameter was defined as puberty.

In the mature females, the stage was divided into three; the *first ovulation stage* where a female whale has a new corpus luteum (sometimes two new corpora lutea are found), the *ovulation stage* where she has both a new (sometimes two) and some old corpora lutea, and the *resting stage* where she has some old corpora lutea and her Graafian follicle is less than 30 mm in diameter. The female whose Graafian follicle is more than 30 mm in diameter, though she has only some old corpora lutea is included in the *ovulation stage*.

The *lactating whales* were defined as those who were found to be capable of secreting milk in mammary glands and who did not have any new corpus luteum or a Graafian follicle more than 30 mm in diameter. As the results of these definitions it was believed that from the process of the development of a Graafian follicle, existence or non existence of the new and old corpus luteum, the diameter of the old corpus luteum in a breeding area which different from a feeding area in the Antarctic or the Aleutian waters. The author divided into two groups; the first group who brought up the calves last year and have

TABLE 1. SIZE DISTRIBUTION OF THE WHALES CAUGHT ACCORDING TO PHYSICAL CONDITIONS

| Body length in feet | Male whale | | | Female whale | | | | | | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mature | | | | | | |
| | Immature | Mature | Total | Immature | Puberty | Ovulating | | Resting | Lactating | Sum | Total | |
| | | | | | | First | Multipola | | | | | |
| 28 | | | | 1 | | | | | | | 1 | 1 |
| 29 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 31 | 1 | | 1 | | | | | | | | | 1 |
| 32 | 2 | | 2 | 2 | | | | | | | 2 | 4 |
| 33 | 2 | | 2 | 1 | | | | | | | 1 | 3 |
| 34 | 2 | | 2 | 3 | | | | | | | 3 | 5 |
| 35 | 8 | | 8 | 10 | | | | | | | 10 | 18 |
| 36 | 11 | | 11 | 7 | 1 | | | | | | 8 | 19 |
| 37 | 3 | 3 | 6 | 5 | 3 | | | | | | 8 | 14 |
| 38 | 3 | 2 | 5 | 4 | 1 | | | | | | 5 | 10 |
| 39 | 3 | 2 | 5 | 2 | 3 | 1 | 1 | | | 2 | 7 | 12 |
| 40 | | 4 | 4 | 1 | | 1 | | | 1 | 2 | 3 | 7 |
| 41 | 1 | 4 | 5 | 1 | | 3 | 2 | 2 | 3 | 10 | 11 | 16 |
| 42 | | 4 | 4 | | | | 4 | 4 | | 8 | 8 | 11 |
| 43 | | 6 | 6 | | | 1 | | | 3 | 4 | 4 | 11 |
| 44 | | 1 | 1 | | | | 6 | | 1 | 7 | 7 | 8 |
| 45 | | 2 | 2 | | | | 7 | 1 | 1 | 9 | 9 | 11 |
| 46 | | | | | | | 5 | | 3 | 8 | 8 | 8 |
| 47 | | 2 | 2 | | | | 2 | | | 2 | 2 | 4 |
| 48 | | | | | | | 1 | | 1 | 2 | 2 | 2 |
| 49 | | | | | | | 1 | | | 1 | 1 | 1 |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | 1 | 1 | 1 | 1 |
| Total | 36 | 30 | 66 | 37 | 8 | 6 | 29 | 7 | 14 | 56 | 101 | 167 |
| Average length | 35.5 | 41.4 | 38.3 | 35.8 | 37.8 | 40.8 | 44.8 | 42.1 | 44.1 | 43.7 | 40.3 | 39.6 |
| Sex ratio | | | 39.5 | | | | 43.8 | | | | 60.5 | 100.0 |
| Maturity rate | 54.5 | 45.5 | 100.0 | 36.7 | 7.9 | (5.9 | 28.7 | 6.9 | 13.9) | 55.4 | 100.0 | |
| Rate of ovulation | | | | | | | 62.5 | | | 100.0 | | |
| Rate of lactating | | | | | | | | | 25.0 | 100.0 | | |
| Rate of under size | 10.6 | | 100.0 | 6.9 | | | | | | | 100.0 | |

Rate of under size for total animals was 8.4%, and rate of immature animal was 43.7%.

weaned them this year and the second group who have been delivered of the calves and have been bringing them up this year.

In comparison of the results in 1959 and 1960, sexually immature whales, 32.3% of all in 1959 went up to 43.7% in 1960. This cause does not consist in the small difference of the female rate, 36.7% this year against 36.5% in 1959 but in the increasing rate of males, 54.5% this year against 36.2% in 1959.

It is known according to the investigations on humpback whales in Ryukyuan waters in 1959 and also in other waters that the migration begins with the young male group. Therefore in the season like that of this year when whaling started at the beginning of migration, it was considered that the rate of immature males increased. In the same reason there are naturally many whales whose body length are under the limitation, and it is attributed to this that the rate of under sized whale, 3.7% for 1959 went up to 8.4% for this year.

Fig. 2 shows the items in Table 1 according to the period. The period was classified by each month in 1959, but this year by the peak of the catches. There are four peaks; from Dec. 28th to Jan. 31st, Feb. 1st to Feb. 22nd, Feb. 23rd to March 18th, March 19th to April 29th. In the first period as explained before, there are many immature groups, especially immature males.

As the season goes on, the average body length becomes longer, and it is easily understood that the male body length in the first period is short. Also the mature female whales increase in number, especially the rate of the lactating whales increased with the advance of period. This explains as last report, that the whales remaining to die in these waters are the females which have been delivered of the calves and have been bringing them up this year. Judging from this phenomenon, the delay of the season gives an unfavorable influence on the resources.

One more data for the early start of this season in comparison with the whale migration is the periodic change of the thickness of blubber. The measured thickness of blubber divided by body length was calculated and averaged in each period in Fig. 3. In the arrangement of data in 1959 and 1960 (according to the lunar calendar), not only the trend of the decrease but also the rate of value against the body length is the same in both years. Particularly the data on males is quite similar. It is proved by many species that the relationship between fatness and thinness follows a way by the migration. Though blubber becomes thinner while migrating in these waters, this year the catch started in the period when it was thicker than last year.

The other items which are shown by the change of blubber thickness

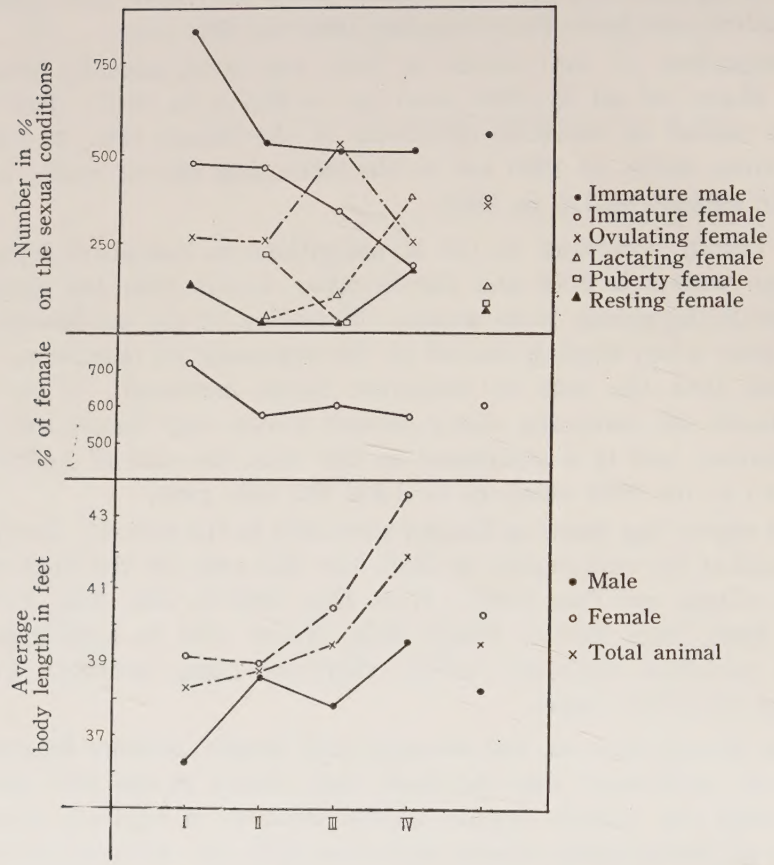



Fig. 2. Average length, sex ratio and percentage of sexual conditions on each period.

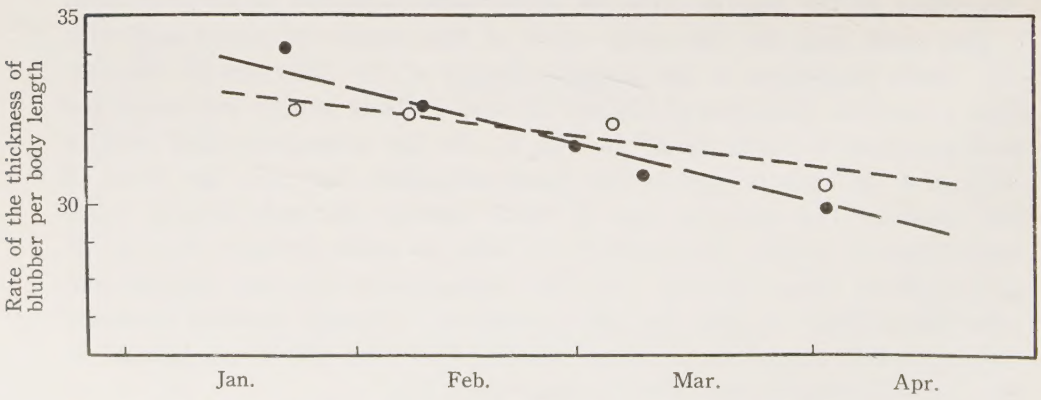



Fig. 3. Monthly decreasing rate of the thickness of blubber.

quite agree with the last report, as the explanation is omitted.

## EXAMINATION FROM GENITAL GLANDS

The weight of the testis was all measured this year and gave almost the same result as that of the data for 1959. Fig. 4 is shown the

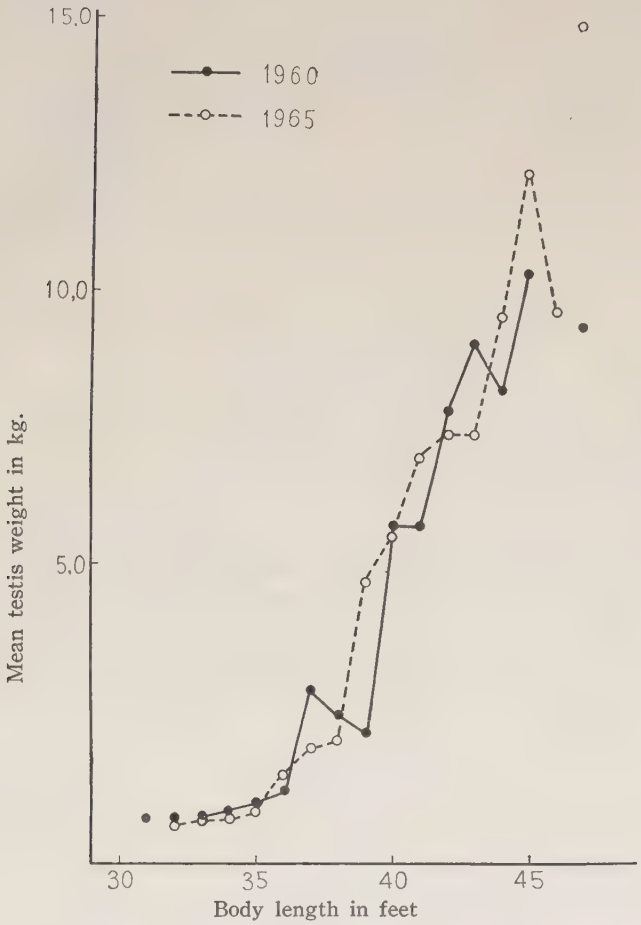



Fig. 4. Geometric means of testis weight according to body length.

geometric means of testis weight according to the body length. On the supposition that the testis weight, when the whale gets sexually mature is 2.0 kg, the mature body length is between 37 and 39 feet. In female, the relationship between body length and total ovulation numbers is shown in Fig. 5, and the body length at the sexual maturity is between 39 and 40 feet. Other items are all similar to those in 1959.

Not a single data is found to change the schematic figures of the

humpback stock in Fig. 6 of the last report (in the Scientific Reports of the Whales Research Institute, No. 14) which was studied mainly from the physiological point of female whales.

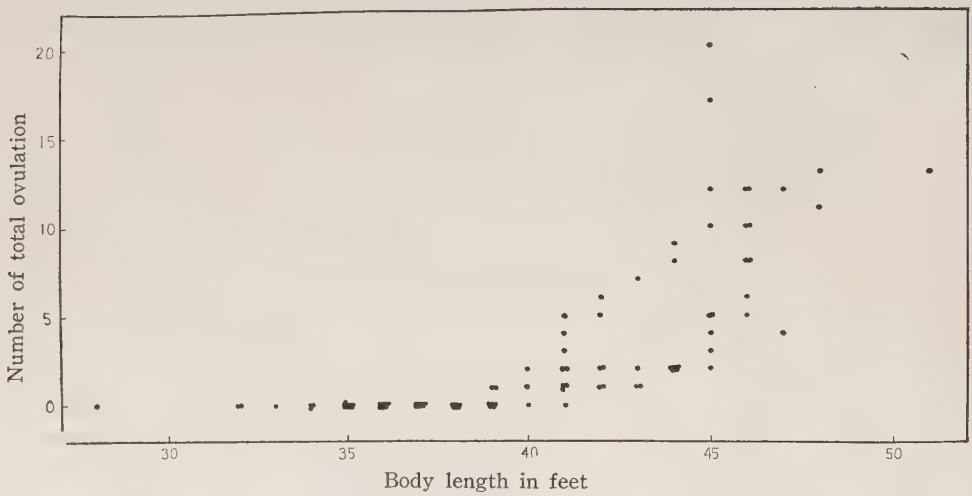



Fig. 5. Relation between body length and total ovulation number.

## RELATIONSHIP BETWEEN BODY LENGTH AND EAR PLUG

The relationship between body length and ear plug is shown in Fig. 6. The mean growth curve in this figure is taken from the report for 1959, and it is understood that the data both last year and this year show the same result. The fact in these items shows that the group of humpback whales migrating in the Ryukyuan waters this year is no other than the North Pacific stock of humpback whales of those previously reported.

## STOMACH CONTENTS

No food has been found in the stomach under the investigation before April, and two samples were found to contain small shrimp type Crustacea in April. It was after the author left the islands, and the specimen were not checked. They, however, seems to be *Euphausia similis*, and the whales perhaps start feeding about this time of the year.

## PARASITIC ANIMAL

The infection rate of the parasitic animals, being similar to that of 1959 leaves nothing to be explained. The data giving the effective suggestions on migration were not available, but it was a rare case that some *Nematoda* species were found in the stomach and intestine of a whale.

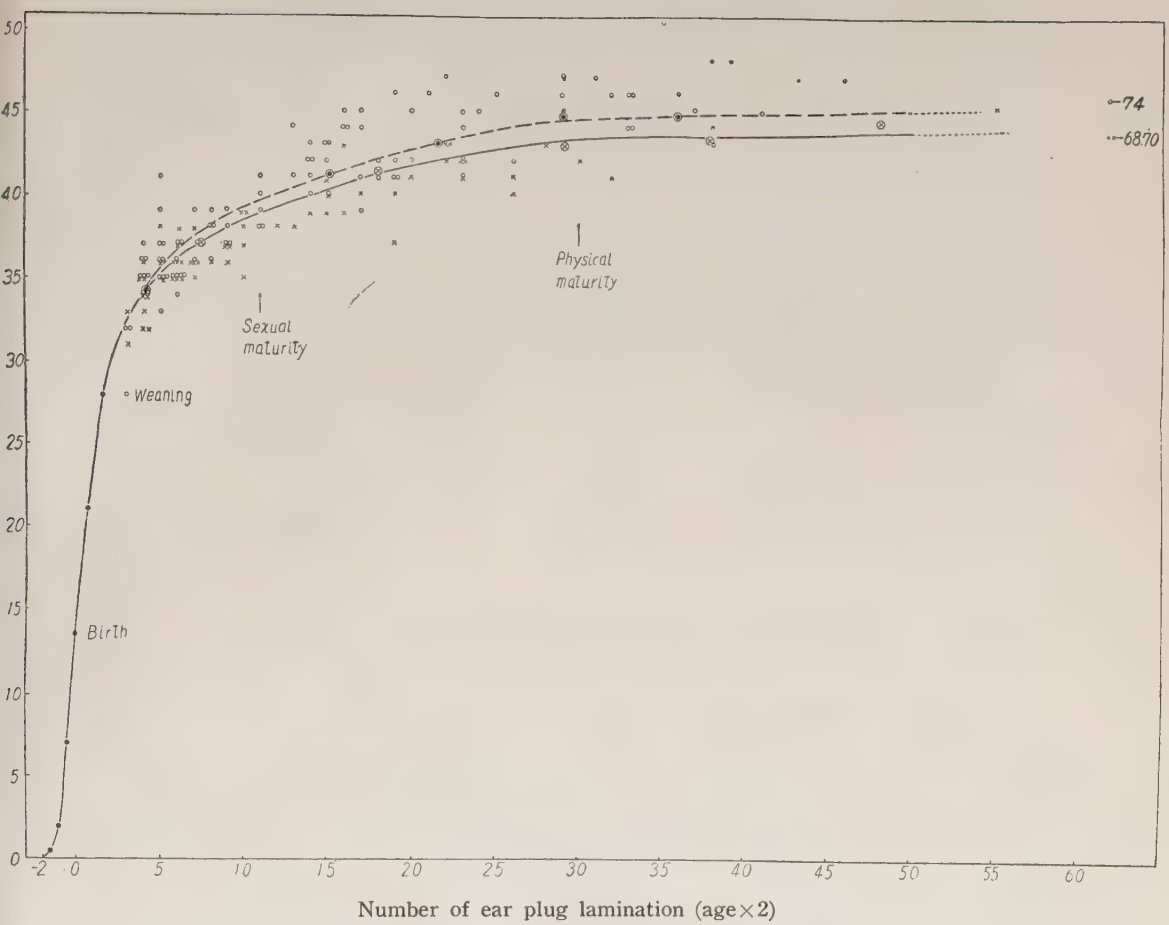



Fig. 6. Growth curve of body length according to the number of laminations in ear plug (age).
Cross and solid line: male, open circle and broken line: female.

## BODY COLOUR

In Table 2 there is a classification of white pattern distribution on the abdominal side according to the same standard in 1959. In the grade 1 or the black humpback group the percentage of occurrence is quite similar in these two years. In the grade 2 decreased it in this year, and in the grade 3 increased.

It is interesting to notice the tendency that there are more females than males with white pattern on the abdominal side in both years, but it is difficult to discriminate the migration groups only from this data.

TABLE 2. OCCURRENCE OF BODY COLOR OBSERVED

| Period | Sex | Grade of body color 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Dec. 28 ~ Jan. 31 | Male | 6 | 0 | 0 | 0 |
| | Female | 12 | 1 | 2 | 0 |
| Feb. 1 ~ Feb. 22 | Male | 23 | 0 | 0 | 0 |
| | Female | 26 | 4 | 1 | 0 |
| Feb. 23 ~ Mar. 18 | Male | 23 | 1 | 1 | 0 |
| | Female | 36 | 1 | 2 | 0 |
| Mar. 19 ~ Apr. 29 | Male | 12 | 0 | 0 | 0 |
| | Female | 16 | 0 | 0 | 0 |
| Total | Male | 54 | 1 | 1 | 0 |
| | Female | 90 | 6 | 5 | 0 |
| | Animal | 144 | 7 | 3 | 0 |
| % of occurrence | | 93.5 | 4.6 | 1.9 | |

## FREQUENCY OF OCCURRENCE OF BLOOD TYPES AND MIGRATION OF WHALES

(Examined by Mr. Kazuo Fujino of our Institute)

The similar method to that in 1959 was used in classifying the blood types, from Type 1 to Type 4. In Table 3 is shown the frequency of occurrence of Type 4 was almost the same in these two years, but there was a considerable difference in the frequency of occurrence between Type 1 and Type 3.

As far as the recovered whales which had been marked were concerned, there were three in 1958, one in 1959 and one in 1960. The captured ones in 1958 and 1960 were all marked in the Aleutian waters

TABLE 3. FREQUENCY OF OCCURRENCE OF BLOOD TYPES COMPARED WITH THE LAST YEAR

| Blood type | Occurrence 1959 Number | 1959 Per cent | 1960 Number | 1960 Per cent |
|---|---|---|---|---|
| 1 | 1 | 1.0 | 2 | 2.35 |
| 2 | 4 | 4.0 | 8 | 9.4 |
| 3 | 7 | 7.0 | 2 | 2.35 |
| 4 | 87 | 87.0 | 73 | 85.9 |
| 5 | 1 | 1.0 | 0 | 0.0 |
| 2 or 3 | 100 | | 85 | |

in 1956. The captured one in 1959 was marked in the same area in 1954. In 1954 there were much more marked whales than in 1956. If the humpback whales from the North Pacific consist of the only one population to mix equally and migrate together, it is said with safety that several of the marked whales in 1954 ought to be recovered.

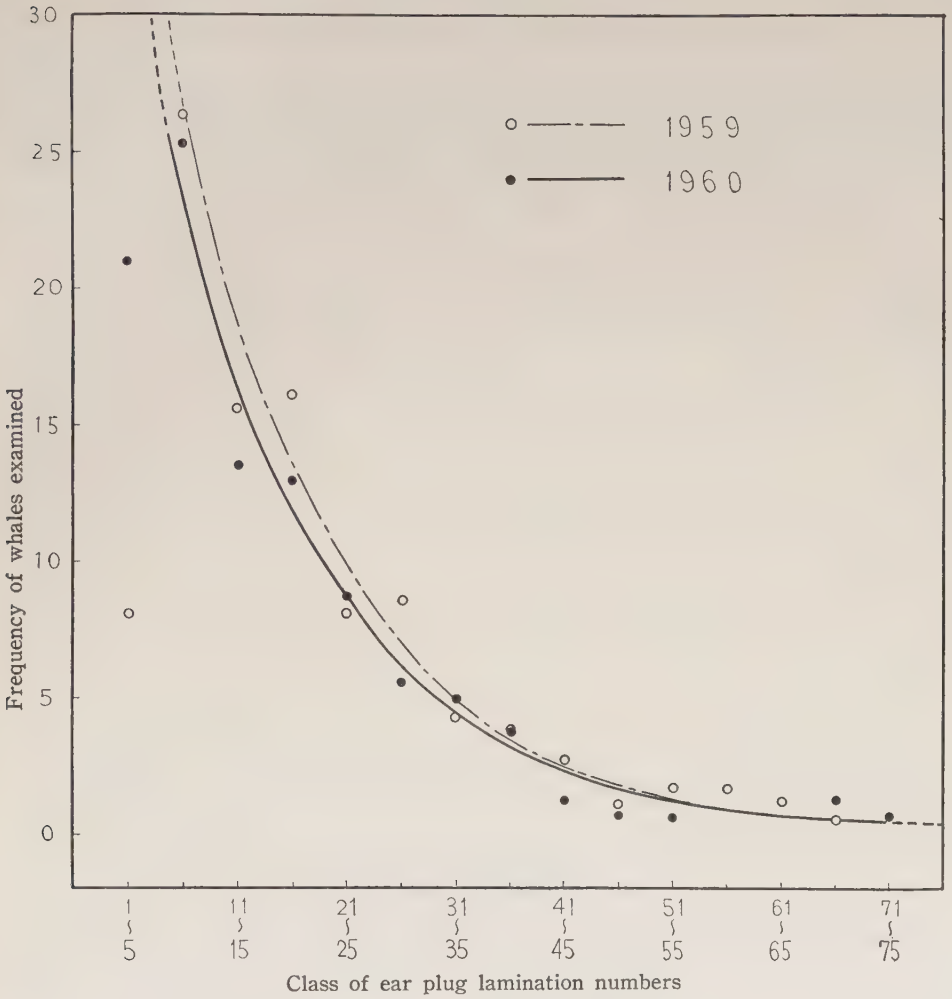



Fig. 7. Frequency curve of whales caught according to ear plug lamination.

If the mixture is equal in the blood type, the frequency of the occurrence also ought to be similar, too. It is presumed by the difference of the recovering rate of marked whales and the rate of occurrence of the blood types in both years that the captured group of the humpback whales migrating in Ryukyuan waters in 1958 is the same group in 1960, being different from the group in 1959. In other words the humpback

whales from the Aleutian waters may be regarded not to be of one group but to be of the groups that migrate in turn every other years. In order to reach the conclusion the studies on the heredity of blood types and the marking investigations are necessary as well as the data collection in the Aleutian water.

## PRESUMPTION OF STOCK FROM EAR PLUG SURVEY

The collection of ear plugs to supply us with the most suitable data on the age determination is due to the great cooperation of the Fisheries Agency of the Government of Ryukyu Islands as well as the recogni-

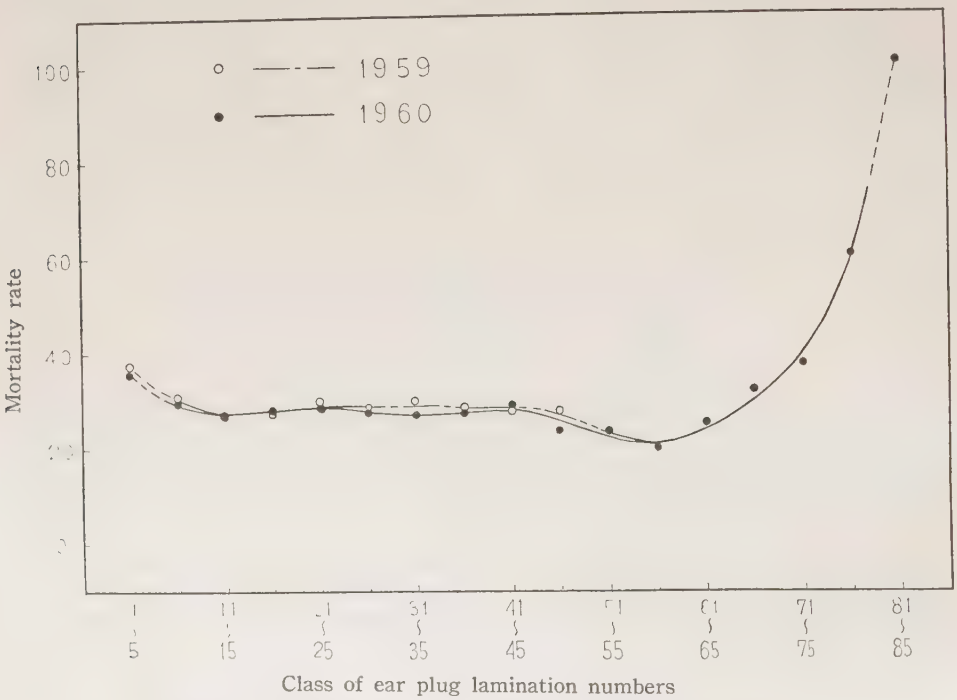



Fig. 8. Mortality curve according to ear plug lamination.

tion of its significance and the progress of collecting techniques. The data from the ear plugs of 162 whales among the 167 catches for this year has been used successfully.

Owing to the small number catches, individual data was summed up in each 5 laminations, and then the frequency was calculated. It was thus used to presume the stock of whales. In Fig. 7 is the frequency curve according to the ear plug laminations.

The mortality curve which was based on the above items is shown in Fig. 8. Both of these curves are quite similar to those of last year.

In Fig. 7 there is a small decrease. It is considered that, however, the effect of the present catches do not give a considerable decrease on the stocks.

## CONCLUSION

The above mentioned results in each item have been summarized as follows.

1. It may be reasonable to think over the late migration of the humpback whales according to the lunar calendar. Therefore the migrating period of the main group in the next season will be from early in December to late in February in the lunar calendar, or from January 10th to the middle of April in the solar calendar.
2. Judging from the biological investigations, the humpback whales are apt to decrease in number year by year. The stock may not be small enough to be indicated by the catches. The main cause of the decrease of migrations (known by sights and catches) is an unfavorable weather especially an unusually greater amount of windy days when a blow could not be found.

It is still unknown whether the humpback whales will be intelligent enough to change their migrating routes because of the increase of catching intensity. The further investigation is necessary to solve this problem.

3. This whaling season started too early and therefore they became impatient not to choose the whales. As a result this brought the decrease of average body length and the increase of the catching rate of immature whales.

Afterward, a bad weather and strong wind at the time of the migration of the main group also brought the decrease of discoveries and of the catches, even per a catching effort. Therefore there was an increase of the catches below the catching limit, but fortunately they were only 8.4% of all. The main cause of the decreasing tendency of stocks which has been mentioned above must be taken great care of.

4. The whales before the main group migrate, mainly consist of young, small whales, as has been considered. The whales that remain after the main group is gone, are the females bringing up the calves. From this fact the best time of the seasons must be adequately chosen and the intensive operations must be made. The method of prolonging the season and spending as much as all gained ought to be abandoned without hesitation.

There are usually male whales though young and small before the migration of the main group, and the early start of the season seems

to have little drop on the stocks.

5. Judging from the recoveries of the marked whales and the rate of occurrence of blood types, the same group does not migrate every year. If some groups migrate wilfully all over the North Pacific waters, and one of them migrates to the islands in turn, the stocks all over these waters must be taken into consideration.

In order to make these facts sure, it is necessary to continue whale marking in Ryukyuan, Aleutian and California waters and also to continue biological investigations. This requires a great deal of time, and if, for instance, during that time A and B groups among all that gather to the Aleutian area to seek for food, migrate to Ryukyuan waters, and C and D groups do not happen to migrate, it will be a serious condition to the Ryukyuan whaling.

The safety operation is to be made if the quota is fixed against the worst conditions. It is important after all to find the standard numbers of migrating whales in the Ryukyuan waters. In this season the decrease of discoveries which occurred by many causes increased catching intensity a good deal. As a result the profit was not large in proportion with the expense. The whale stocks are limited and therefore the profitable operations must be made.

In order to make this possible, incooperation of the organizations, decrease of the number of catches, and use of small numbers of excellent boats are thought necessary.

## ACKNOWLEDGEMENT

In concluding the report for the season of 1960, the author wishes to thank every one concerned for his kindnesses suggestions and assistances. All the efforts that the officials of USCAR had to make the Ryukyuan whaling an enduring industry set a good example to us, and they were heartedly appreciated.

The author must particularly acknowledge his request of the cooperation of the U.S. helicopter troop. With this, our work proved more fruitful than last year.

The author has a great admiration for the earness of the Ryukyu Government officials to the development of the whaling industry, which can be grasped through the mastery of the techniques by the whaling inspectors and their fine leadership given to the Fisheries Agency, and besides this he expresses his hearty thanks for their cooperation to the investigations.

Great thanks are also due to each member of the Ryukyuan whaling association who has always given a big favor in spite of the unexpected

depresses operations.

The author is quite indebted as well to the Ryukyu Suisan Company for their kindness in keeping the frozen blood and to Mr. Rikio Kuroiwa director of Nitto Whaling Company for carrying the samples to Tokyo with him by airway.

## REFERENCES

CHITTLEBOROUGH, R. G. (1958). The breeding cycle of the female humpback whale, *Megaptera nodosa* (Bonnaterre). *Aust. J. Mar. Freshw. Res.*, 9(1):

——— (1959a). Determination of Age in the humpback whale, *Megaptera nodosa* (Bonnaterre). *Aust. J. Mar. Freshw. Res.*, 10(2):

——— (1959b). Intermingling of two population of humpback whales. *Norsk Hvalfangst-Tid.*, 48(10):

DAWBIN, W. H. (1960). An analysis of the New Zealand catches of humpback whales from 1947 to 1958. *Norsk Hvalfangst-Tid.*, 49(2):

NISHIWAKI, M. (1959). Humpback whales in Ryukyuan waters. *Sci. Rept. Whales Res. Inst.*, no. 14:

# RELATIVE GROWTH OF THE FIN WHALE, *BALAENOPTERA PHYSALUS* (LINN.)

SEIJI OHSUMI

## INTRODUCTION

Hetherto, the growth of whales have been mainly studied as the function of time. It is natural to regard time as a factor concerning the growth, because the growth is related to time. But as stated by Shimizu (1959), the significance of the astronomical time for the life is merely relative to the nature of life itself and in the relation between the life and environment.

Calendar age does not represent the true age of the life (Hammond, 1950) On the other side, the age study of whales has been developing recently, but the true age of whales is not known except the whales which are born and are kept in the aquarium. That is to say, we cannot know even if the calendar age in the whales. Therefore, it is not complete to study the growth of whales only as the function of the astronomical time, and it will be reasonable to study of growth as the function of the condition of growing system itself.

Now, Huxley (1932) showed experientially that if $x$ and $y$ are supposed to presume as the two portions in the same growing system, the relation of the two is represented as the following formula: $y=bx^{\alpha}$ ($b$ and $\alpha$ are constant). In this formula, term of time is not included and the time is only a latent factor. We can say that relative growth stands on the biological time. The formula $y=bx^{\alpha}$ is called allometry formula.

In the study of the absolute growth, only the increase in quantity is examined accompanying the process of time. However, the portion of living body is merely the portion as the general harmony of the living body, and the symmetry of living body changes every moment. According the study of relative growth we can examine the relation between the two portions and the development of the form in the growing system.

In the whales, the body proportions have been measured by many taxonomists, but most of them have not measured in the consideration of relative growth. Mackintosh & Wheeler (1929) measured the many portion of the body of southern blue and fin whales for the purpose of the separation of races. And they showed the change of body proportion with the increase of body length. This will be the first sign of the idea on the relative growth.

Matthews (1937, 1938a, b) measured the body parts on the southern

humpback, sperm and sei whales, and he adopted the allometry formula for the measurements. After then, there have been fairly many reports on the body proportion of whales. Limiting the fin whales, Matsuura & Maeda (1842) measured the body proportion on the fin whale caught in the adjacent waters to Kamtchatka Penninsula. Fujino (1954) compared the body proportions among the fin whales in the northern Pacific, adjacent water to Japan, and the Antarctic. Ichihara (1957) studied the differency of the stocks between the northern Pacific and the East China Sea fin whales applying the linear decriminent function.

Above reports are all works mainly to compare the change of proportion on the subject to separate the stocks and the comparison is took place only in the small range in the growing system, that is to say, in mainly the adult whales over weaning.

Mackintosh & Wheeeler (1929) measured the body proportions of foetuses, but they stated that they did not discuss on the foetuses because of the scanty of samples. Zemskiy (1950) reports on the body proportion oí the southern fin whale foetuses. Laboratory of the Enoshima Aquarium reports the change of body proportion of four stages in growing system (middle and large foetuses, calves and adults) of the bottlenosed dolphins. Shimizu (1959) discusses the $\alpha$-values of alometry formula in the foetal stage and adult stage of the blue whales using the data by Mackintosh & Wheeler (1929).

I have studied the growth of fin whales, and in this report, the relative growth of fin whales will be discussed.

Hitherto, many measurements of body proportion of fin whale have been reported in the adult stages. But in the foetal stages, the data on the subject have been scanty. Now, I have measured the body parts of the foetuses in the North Pacific and the Antarctic. And I could study the relative growth in the wide ranges of the growing system. I did dot study the relative growth of fin whales in the earlier developemental stages under 10 cm long in body length in this paper, I will report on this subject in future.

Meanwhile, the body proportions are compared between the Antarctic and the northern Pacific fin whales chiefly in the foetal stages. Lastly, interspecies relative growth is also compared within the six species classified in the *Balaenopteridae*, that is to say, *Balaenoptera musculus*, *B. physalus*, *B. edeni*, *B. borealis*, *B. acuto-rostrata* and *Megaptera novaeangliae*.

## MATERIALS AND METHODS

Mackintosh & Wheeler (1929) appointed 26 measurement body parts of

the blue and fin whales from South Georgia and South Africa, and measured the straight length of these parts in parallel with the body axis. Matsuura & Maeda (1952) and Fujino (1954) adopted the same body parts as the Mackintosh & Wheeler on the study of body proportion of the North Pacific fin whales.

TABLE 1. MEASUREMENT NUMBER AND THEIR BODY PARTS

| Measurement No. | Body parts measured |
|---|---|
| 1 | Total length |
| 3 | Tip of snout to blow-hole |
| 5 | Tip of snout to center of eye |
| 6 | Tip of snout to tip of flipper |
| 7 | Center of eye to center of ear |
| 8 | Notch of flukes to posterior emargnation of dorsal fin |
| 9 | Flukes, width at insertion |
| 10 | Notch of flukes to center of anus |
| 11 | Notch of flukes to umbilicus |
| 12 | Notch of flukes to end of system of ventral grooves |
| 13 | Center of anus to center of reproductive aperture |
| 14 | Vertical height of dorsal fin |
| 15 | Length of base of dorsal fin |
| 17 | Anterior end of lower border to tip of flipper |
| 19 | Greatest width of flipper |
| 25 | Flukes, notch to tip |

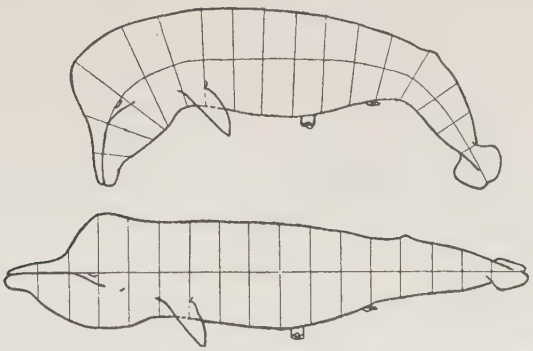


Fig. 1. Modification of the shape of small foetus for the measurement of body proportions. Female fin whale foetus, 18.6 cm long.

In this paper, I also use the same body parts and method as Mackintosh & Wheeler for the purpose of the comparing my data with the previous reports. The body parts measured in this paper are as shown in Table 1. In this paper, the body parts which are discussed from now on, will be represented by the measurement number as shown in this table.

Measurements are took place newly on the over 10 cm long foetuses of fin whales caught by Japanese fleets in the North Pacific and the Antarctic. On the fin whale foetuses over one meter long, the body length

are able to be measured by the straight length between the tip of snout and the notch of flukes. And the body axis are recognized as the straight line. But as the heads are bend under one meter long foetuses and tails are bend under 20 cm in body length, the body axis become curved. In these shape the comparison of the proportion cannot be took place, therefore I straightened the body axis as shown in Fig. 1 and measured the body parts.

TABLE 2. NUMBER OF FIN WHALE FOETUSES MEASURED

| Body length (cm) | Antarctic | | | Northern Pacific | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Males | Females | Total | Males | Females | Total | Males | Females | Total |
| 1~125 | 2 (2) | 3 (2) | 5 (4) | — | 3 (3) | 3 (3) | 2 | 6 | 8 |
| 26~50 | 4 | 4 | 8 | 3 (2) | 2 (1) | 5 (3) | 7 | 6 | 13 |
| 51~75 | 8 (2) | 5 (2) | 13 (4) | 6 | 3 | 9 | 14 | 8 | 22 |
| 76~100 | 7 (1) | 6 (1) | 13 (2) | 9 | 6 | 15 | 16 | 12 | 28 |
| 101~125 | 5 | 4 | 9 | 5 | 5 | 10 | 10 | 9 | 19 |
| 126~150 | 3 | 5 | 8 | 8 | 10 | 10 | 11 | 15 | 26 |
| 151~200 | 7 | 8 | 15 | 12 | 16 | 28 | 19 | 24 | 43 |
| 201~250 | 4 | 8 | 12 | 3 | 5 | 8 | 7 | 13 | 20 |
| 251~300 | 6 | 7 | 13 | 8 | 4 | 12 | 14 | 11 | 25 |
| 301~350 | 2 | 6 | 8 | 3 | 2 | 5 | 5 | 8 | 13 |
| 351~400 | 6 | 3 | 9 | 1 | 2 | 3 | 7 | 5 | 12 |
| 401~450 | 2 | 5 | 7 | — | 1 | 1 | 2 | 6 | 8 |
| 451~500 | 1 | 2 | 3 | — | 1 | 1 | 1 | 3 | 4 |
| 501~550 | 1 | 1 | 2 | — | — | — | 1 | 1 | 2 |
| Total | 58 | 67 | 125 | 58 | 60 | 118 | 116 | 127 | 243 |

( ): formalin fixed

Over one meter long foetuses are measured on board the factory ship soon after the extraction from the uterus of the mothers. In under one meter long foetus, there are some individuals measured after 5–10% formalin fixation.

Data on the foetus measurements in this paper are shown in Appendix I and II. And table 2 shows the number of foetuses which are measured for this paper classified the body length classes. Total foetuses measured are 243. Mackintosh & Wheeler (1929) measured the body proportion on the 80 fin foetuses, and Zemskiy (1950) also measured on the 66 foetuses. But in their papers individual measurements are not shown, and I cannot use the data.

On the measurement of the adult fin whales, I use the data given by Mackintosh & Wheeler (1929) in South Georgia and the data given by Fujino (1954) in the northern part of the North Pacific. For the study of the interspecies relative growth, I adopt the measurement data given by the following authors.

| | |
|---|---|
| Mackintosh & Wheeler (1929): | *Balaenoptera musculus B. physalus* |
| Omura, Nishimoto & Fujino (1952): | *B. edeni.* |
| Mathews (1938, 1937): | *B. borealis, Megaptera novaeangliae* |
| Omura & Sakiura (1956): | *B. acuto-rostrata* |

And 19 measurement data on *Balaenoptera acuto-rostrata* from the coast of Japan are newly shown in Appendex III.

## ALLOMETRY FORMULA

### RELATIVE GROWTH BETWEEN TWO MEASUREMENTS OF THE SOUTHERN FIN WHALES

Huxley (1932) showed experimentially that if the two parts in the growing system is $x$ and $y$, the relation between the two is shown by $y=bx^{\alpha}$.

Logalismic relation of above formula is shown as follows:

$$\log y=\log b+\alpha \log x$$

As this is a linear function, we will get straight line if the measurement figures of the portion of $x$ and $y$ put on the logalismic section paper.

Then, the measured figures are plotted in the logalismic section papers according my data on foetuses and the table (p. 324–5) by Mackintosh and Wheeler (1929) on adult fin whales in the Antarctic. On using the table by Mackintosh and Wheeler, I changed the percent of body length into the mean length in the every one meter classes. The range of body length is from 10 cm till 2,500 cm.

Fig. 2 shows the relative growths between body length and Nos. 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 19 and 25, between No. 14 and No. 15 (on the shape of back fin), between No. 17 and No. 19 (on the shape of flipper) and between No. 9 and No. 25 (on the shape of flukes). Except the measurement of No. 13, there is no sexual differentiation between males and females in the allometry. Mackintosh & Wheeler (1929) already state that the only marked difference in body proportion between sexes is that shown by measurement No. 13 on the adult fin whales. Moreover, it is clear in this paper that this phenomenon is also seen in the relative growth of the foetal stage. And in over 10 cm long fin whale foetuses, marked difference in relative growth between sexes is shown in measurement No. 13.

Individually relative growths are examined as follows:

1. *No. 1–No. 3.* This shows the four-phasic allometry. The critical points are seen in the body lengths of 110 cm, 1,140 cm and 2,100 cm.
2. *No. 1–No. 5.* This shows also the four-phasic allometry. The critical points are seen in the body lengths of 110 cm, 1,200 cm and 2,000 cm.
3. *No. 1–No. 6.* In the foetal stage, the relative growth shows mono-

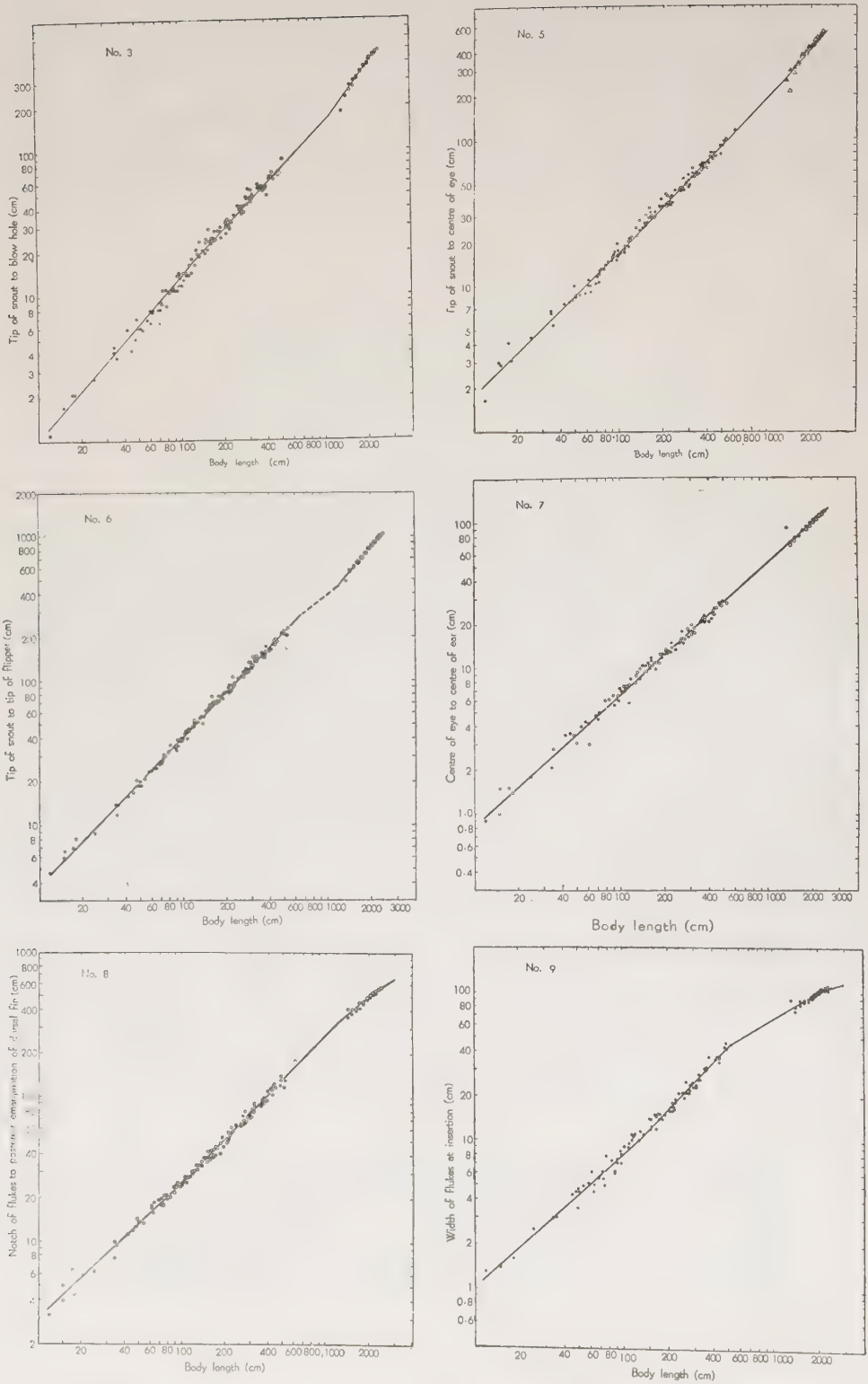

No. 3
Tip of snout to blow hole (cm)
Body length (cm)
No. 5
Tip of snout to centre of eye (cm)
Body length (cm)
No. 6
Tip of snout to tip of flipper (cm)
Body length (cm)
No. 7
Centre of eye to centre of ear (cm)
Body length (cm)
No. 8
Notch of flukes to posterior emargination of dorsal fin (cm)
Body length (cm)
No. 9
Width of flukes at insertion (cm)
Body length (cm)

Fig. 2. Relative growths of the external measurements in the Antarctic fin whales Open circle: female, closed circle: male.

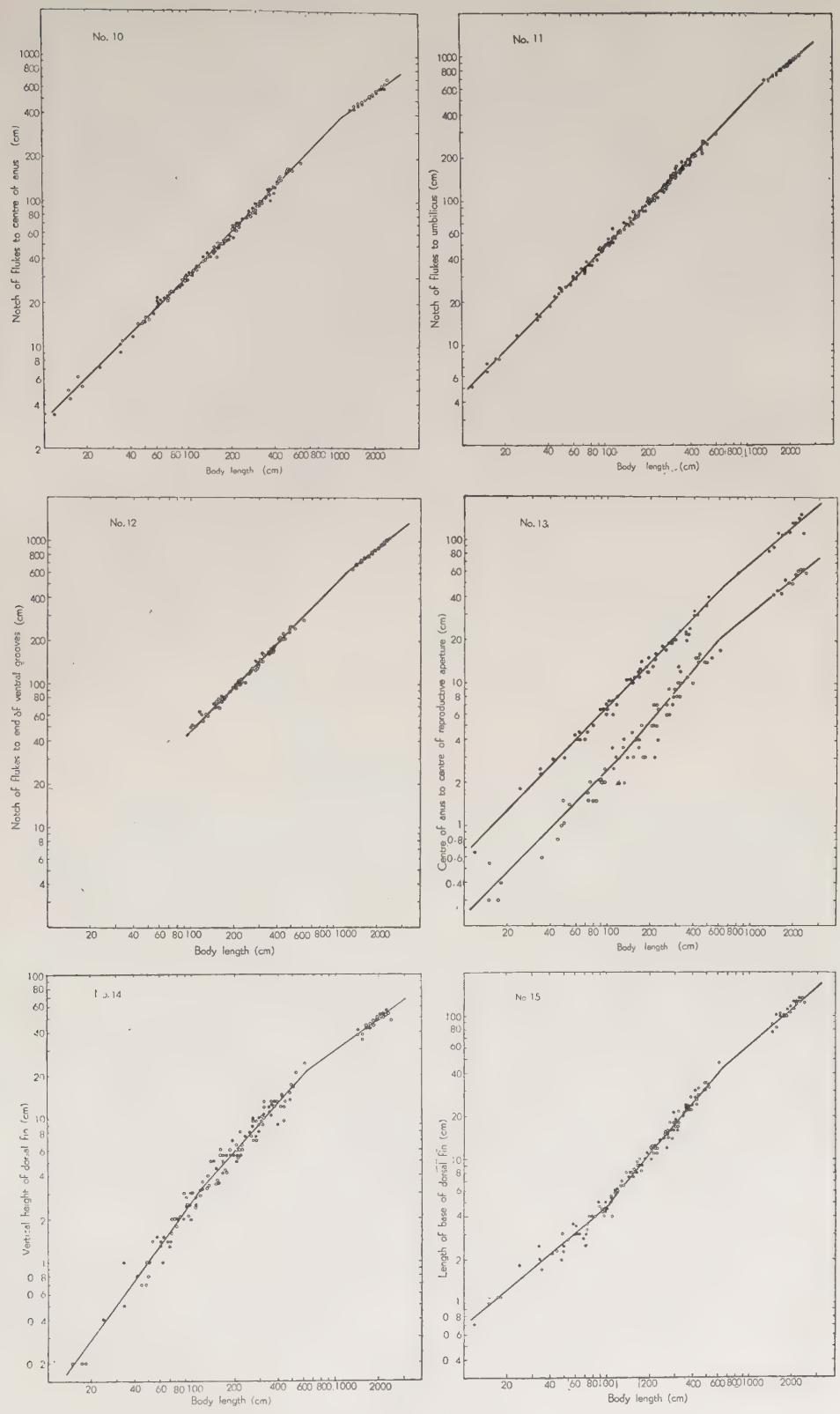

No. 10
Notch of flukes to centre of anus (cm)
Body length (cm)
No. 11
Notch of flukes to umbilicus (cm)
Body length (cm)
No. 12
Notch of flukes to end of ventral grooves (cm)
Body length (cm)
No. 13
Centre of anus to centre of reproductive aperture (cm)
Body length (cm)
No. 14
Vertical height of dorsal fin (cm)
Body length (cm)
No. 15
Length of base of dorsal fin (cm)
Body length (cm)

Fig. 2. (Cont.)

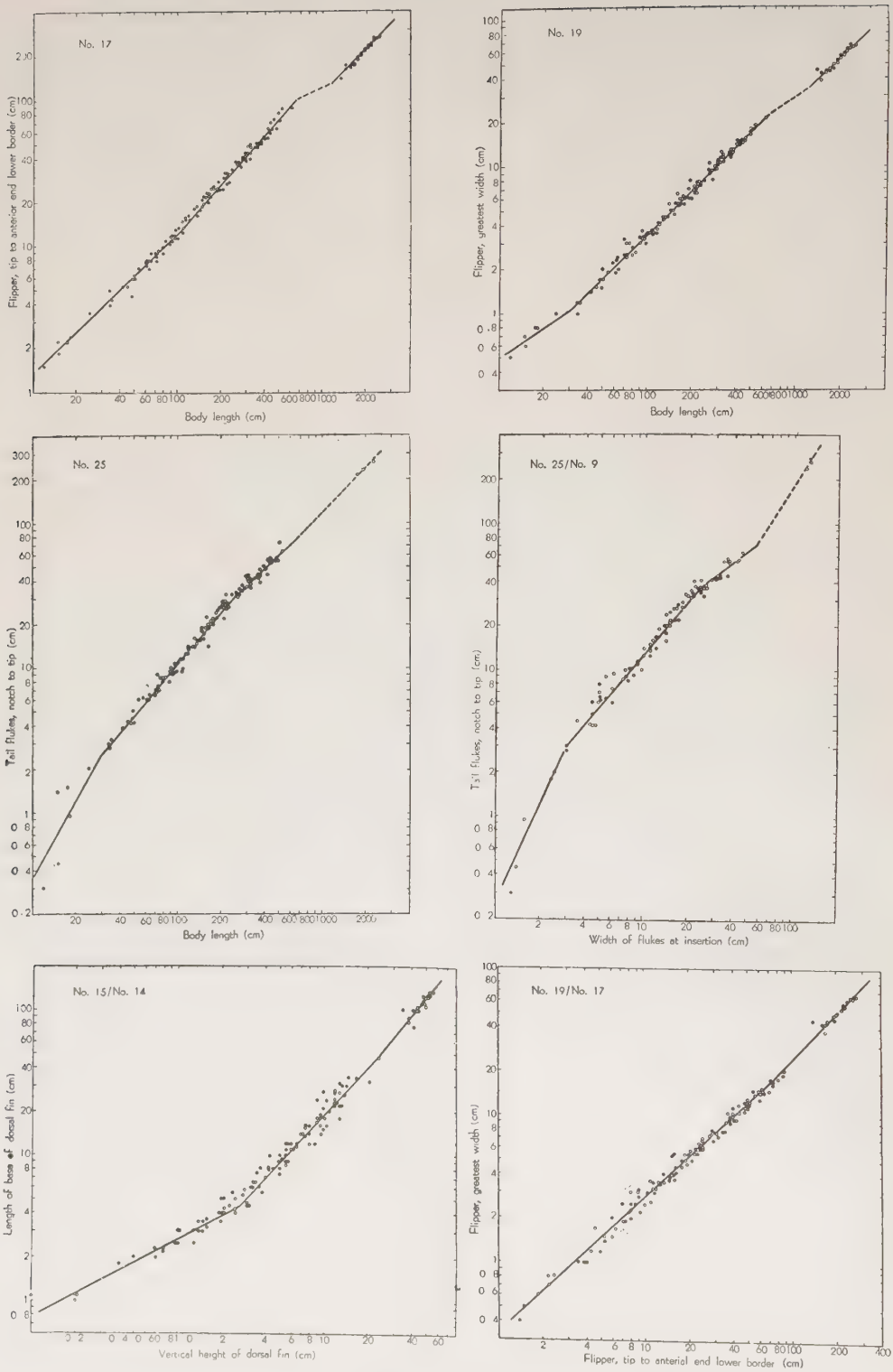

No. 17
Flipper, tip to anterior end lower border (cm)
Body length (cm)
No. 19
Flipper, greatest width (cm)
Body length (cm)
No. 25
Tail flukes, notch to tip (cm)
Body length (cm)
No. 25/No. 9
Tail flukes, notch to tip (cm)
Width of flukes at insertion (cm)
No. 15/No. 14
Length of base of dorsal fin (cm)
Vertical height of dorsal fin (cm)
No. 19/No. 17
Flipper, greatest width (cm)
Flipper, tip to anterior end lower border (cm)

Fig. 2. (Cont.)

phasic allometry and in the adult stage, it shows the diphasic allometry having one critical point in the body length of 2,000 cm. But the allometries of the foetal stages and adult stages are discontinuous. Because it will be the lack of the data in the suckling stage. The allometry formula of the similar animals as the whales cannot be discontinuous. Comparing the relative growth of other measurements, it will be reasonable to put one allometry between 650 cm and 1,200 cm of body length, which represent the body lengths at birth and weaning respective into the relative growth of No. 1–No. 6.

Consequently, the relative growth between No. 1 and No. 6 will be the four-phasic allometry having three critical points in the body lengths of 650 cm, 1,200 cm and 2,000 cm.

4. *No. 1–No. 7.* In the range of body length studying in this paper, there is no critical point. Therefore, it is monophasic allometry.
5. *No. 1–No. 8.* This shows the four-phasic allometry. Critical points are seen in 105 cm, 1,120 cm and 2,100 cm of No. 1.
6. *No. 1–No. 9.* This is the four-phasic allometry, having three critical points in the body length of 120 cm, 530 cm and 2,050 cm.
7. *No. 1–No. 10.* It shows the triphasic allometry. Critical points exist in the body length of 110 cm and 1,120 cm.
8. *No. 1–No. 11.* It shows the diphasic allometry. The body length of 1,160 cm is the critical point.
9. *No. 1–No. 12.* As shown in the future paragraph, the posterior end of ventral grooves of the fin whale appears fairly in the body length of over 90 cm long. And the ventral grooves accomplish the development in over 120 cm long body length. Therefore, the posterior ends of ventral grooves are able to be measured in the individuals over about 90 cm long. This relative growth shows the diphasic allometry having one critical point in the body length of 1,200 cm.
10. *No. 1–No. 13.* Difference of allometry between the sexes in only this relative growth. However, the critical points of the both sexes exist in the almost same body length each other. That is to say, the relative growth between No. 1 and No. 13 shows the triphasic allometry having the critical points in the body lengths of 120 cm, and 600 cm.
11. *No. 1–No. 14.* It shows the triphasic allometry, having two critical points in the body length of 120 cm and 650 cm.
12. *No. 1–No. 15.* Triphasic allometry, critical points: 106 cm and 650 cm.
13. *No. 1–No. 17.* In foetal stage, the relative growth shows the diphasic allometry, having one point in the body length of 107 cm, and in the adult over 1,300 cm long it shows the monophasic allometry.

The relative growth in the foetal stage is discontinuous to that in the adult stage. As similar as the relative growth between No. 1 and No. 6, there is no data on the measurement of suckling stage, it is natural to consider one monophasic allometry in the stage. Then, the relative growth between No. 1 and No. 17 will be represented as the four-phasic allometry, having three critical points at the body lengths of 107 cm, 650 cm and 1,200 cm.

14. *No. 1–No. 19.* It shows the triphasic allometry having critical points in the body length of 30 cm, and 120 cm in the foetal stages. And in the adult stage over 1,300 cm long, it is represented as the monophasic allometry. However, as No. 1–No. 17, in the suckling stage, these two allometries are discontinuous. The total relative growth will be the five phasic allometry, adding the two critical points in the body length of 650 cm and 1,200 cm.
15. *No. 1–No. 25.* In the foetal stage, the relative growth shows the triphasic allometry, having two critical points in the body length of 30 cm and 250 cm. But because of the cutting half of tail flukes pulling the carcase by catcher boat, we have not always chance to in measure No. 25. Therefore, Mackintosh & Wheeler (1929) did not measured this portion for the adult whales. I got chances to measure No. 25 for three female fin whales in the Antarctic. Recording the three measurements, the relative growth between No. 1 and No. 25 seems to show the four-phasic allometry having three critical points in the body lengths of 30 cm, 250 cm and 650 cm.
16. *No. 14–No. 15.* This shows the triphasic allometry. The co-ordinates of the critical points are 2.7 cm; 4.6 cm and 20.2 cm; 44 cm. These figures correspond to the body lengths of 106–120 cm and 650 cm respectively.
17. *No. 17–No. 19.* The relative growth between No. 1 and No. 17 shows the four-phasic allometry, and those between No. 1 and No. 19 shows the five-phasic allometry. However, the relative growth between No. 17 and No. 19 shows the diphasic allometry. The co-ordinate of the critical point is 70 cm and 17 cm. These value do not include in any value of critical points in the relative growths between No. 1 and No. 17 or between No. 1 and No. 19. 70 cm in the No. 17 is the value before birth and 17 cm in the No. 19 is those after birth. Considering both values, the time at birth seems to be the critical point in the relative growth between No. 17 and No. 19.
18. *No. 9–No. 25.* In the foetal stage, this shows the triphasic allometry having two critical points in the values correspond to the body lengths of 30 cm and 250 cm. Although the data are incomplete,

the relative growth seems to be the monophasic allometry. Therefore, the relative growth between No. 9 and No. 25 will be the four-phasic allometry.

Classifying the above eighteen relative growths in the growing system of fin whales over 10 cm long, the result is as follows:

| | |
|---|---|
| Monophasic allometry : | No. 1–No. 7. |
| Diphasic allometry : | No. 1–No. 11, No. 1–No. 12, No. 17–No. 19. |
| Triphasic allometry : | No. 1–No. 10, No. 1–No. 14, No. 1–No. 15, No. 14–No. 15. |
| Four-phasic allometry : | No. 1–No. 3, No. 1–No. 5, No. 1–No. 6, No. 1–No. 8, No. 1–No. 9, No. 1–No. 17, No. 1–No. 25, No. 9–No. 25. |
| Five-phasic allometry : | No. 1–No. 19. |

## COMPARISON OF THE RELATIVE GROWTHS OF THE ANTRACTIC FIN WHALES TO THOSE OF THE NORTH PACIFIC FIN WHALES

It has been considered that the southern fin whales are separated racially from the northern fin whales. Matsuura & Maeda (1942) compared the body proportions of the North Pacific fin whales to those of the southern fin whales and they deduced that both belong to the different races. But they did not compare the body proportion in the same body length classes. Fujino (1954) compared the body proportion of adult fin whales caught in the Japanese coast, northern part of the North Pacific and the Antarctic in each body length classes. And he concluded that no remarkable differences were recognized between the Japanese coastal fin whales and those in the northern Pacific, and the Antarctic fin whale have a larger head and smaller caudal part than the northern Pacific fin whales af ter attaining of sexual maturity, and northern Pacific fin whales possesses more posteriorly situated and smaller dorsal fin, and bigger flippers than the former. Ichihara (1957) compared the body proportion between the northern Pacific fin whales and East China Sea fin whales in the North Pacific by means of the linear discriminent function, and he concluded that there were different shapes of fin whales between the two areas in the North Pacific and fin whales had longer heads and shorter tails in the northern Pacific than in East China Sea.

Above results are all obtained by studying the adult stage of fin whales. I compared the relative growth of fin whales between the Antarctic and the North Pacific, chiefly northern part of the North Pacific from the foetal stage till adult stage. Table 3 shows the average values of each measurements in each body length classes of the foetuses. And the relative growths between two measurements are shown in Fig. 3.

Considering from the figure, the differences of the relative growths

TABLE 3. AVERAGE VALUES OF THE MEASUREMENTS IN EACH BODY LENGTH CLASSES OF THE FIN WHALES

| Body length (cm) | | No. 3 (cm) | No. 5 (cm) | No. 6 (cm) | No. 7 (cm) | No. 8 (cm) | No. 9 (cm) | No. 10 (cm) | No. 11 (cm) | No. 12 (cm) | No. 13 (cm) | No. 14 (cm) | No. 15 (cm) | No. 17 (cm) | No. 19 (cm) | No. 25 (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10~15 | N | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | S | 1.65 | 2.33 | 5.35 | 1.4 | 4.1 | 1.4 | 4.2 | 6.25 | none | ♂ 1.225<br>♀ 0.388 | 0.2 | 0.85 | 1.85 | 0.6 | 0.85 |
| 16~20 | N | 2.00 | 2.97 | 7.61 | 1.4 | 4.86 | 1.73 | 5.60 | 8.30 | none | ♂ —<br>♀ 0.53 | 0.16 | 1.07 | 2.43 | 0.77 | 1.02 |
| | S | 1.90 | 3.50 | 6.80 | 1.25 | 5.2 | 1.45 | 5.325 | 7.05 | none | ♀ 0.425 | 0.43 | 1.1 | 2.025 | 0.7 | 0.975 |
| 21~25 | N | — | — | — | — | — | — | — | — | — | ♂ 1.8 | 0.4 | 1.8 | 3.5 | 1.0 | 2.0 |
| | S | 2.70 | 4.50 | 8.80 | 1.8 | 6.3 | 2.5 | 7.2 | 11.8 | none | ♂ 1.85 | 0.26 | 1.45 | 3.35 | 1.10 | 1.70 |
| 26~30 | N | 2.92 | 3.65 | 11.45 | 2.2 | 6.70 | 2.05 | 7.80 | 11.8 | none | ♂ 1.85 | 0.26 | 1.45 | 3.35 | 1.10 | 1.70 |
| | S | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 31~40 | N | 3.43 | 4.17 | 13.80 | 2.70 | 9.10 | 3.10 | 10.93 | 16.4 | none | ♂ 2.10<br>♀ 0.88 | 0.56 | 1.66 | 4.70 | 1.35 | 3.05 |
| | S | 4.13 | 6.17 | 13.23 | 2.45 | 8.93 | 2.93 | 10.30 | 15.9 | — | ♂ 2.40<br>♀ 0.60 | 0.75 | 2.066 | 4.53 | 1.13 | 3.00 |
| 41~50 | N | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | S | 4.42 | 8.32 | 18.3 | 3.53 | 13.0 | 4.0 | 14.16 | 22.48 | none | ♂ 2.85<br>♀ 1.10 | 0.84 | 2.40 | 5.44 | 1.602 | 4.38 |
| 51~60 | N | 6.75 | 9.00 | 22.25 | 4.0 | 13.5 | 4.5 | 16.6 | 26.3 | none | ♀ 1.25 | 1.30 | 2.75 | 6.25 | 1.50 | 5.2 |
| | S | 6.05 | 8.11 | 20.88 | 3.8 | 13.85 | 4.566 | 16.1 | 25.5 | none | ♂ 4.30<br>♀ 1.35 | 1.23 | 3.00 | 7.066 | 1.93 | 5.466 |
| 61~70 | N | 7.80 | 11.00 | 27.25 | 4.70 | 14.57 | 6.5 | 20.88 | 32.58 | none | ♂ 4.5<br>♀ 1.8 | 1.50 | 3.33 | 8.33 | 2.28 | 6.6 |
| | S | 7.60 | 10.04 | 25.14 | 3.97 | 17.92 | 5.26 | 22.1 | 30.9 | none | ♂ 4.12 | 1.36 | 3.2 | 7.78 | 2.36 | 6.48 |
| 71~80 | N | 9.50 | 12.83 | 30.75 | 5.45 | 19.41 | — | 24.11 | 38.08 | none | ♂ 5.28<br>♀ 2.0 | 1.72 | 4.83 | 10.0 | 2.65 | 8.25 |
| | S | 8.97 | 12.41 | 30.20 | 5.16 | 15.62 | 5.54 | 22.82 | 36.35 | none | ♂ 4.75<br>♀ 1.67 | 1.73 | 3.36 | 8.83 | 2.68 | 7.81 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81～90 | N | 11.77 | 15.45 | 37.8 | 5.80 | 22.11 | — | 27.5 | 42.87 | 46.5 | 5.75 / 2.25 | 2.38 | 4.50 | 12.17 | 3.28 | 10.3 |
| | S | 10.90 | 15.10 | 34.17 | 6.3 | 22.16 | 6.46 | 26.16 | 40.0 | none | 6.5 / 1.8 | 2.36 | 4.56 | 11.06 | 2.86 | 8.0 |
| 91～100 | N | 12.19 | 16.09 | 38.34 | 6.76 | 24.41 | 8.0 | 29.58 | 46.58 | 51.5 | 6.75 / 2.50 | 2.23 | 4.55 | 12.3 | 3.36 | 10.16 |
| | S | 15.60 | 16.86 | 38.87 | 6.35 | 24.77 | 7.29 | 29.03 | 46.15 | 45.25 | 6.5 / 2.16 | 2.49 | 4.43 | 11.82 | 3.30 | 9.71 |
| 101～150 | N | 18.25 | 23.43 | 54.30 | 8.56 | 33.02 | 11.1 | 38.95 | 43.2 | 64.6 | 9.08 / 3.42 | 3.62 | 6.15 | 16.2 | 4.44 | 14.97 |
| | S | 17.35 | 21.56 | 51.90 | 8.37 | 31.61 | 9.92 | 39.71 | 59.49 | 62.20 | 8.99 / 3.11 | 3.485 | 6.10 | 15.75 | 4.17 | 15.47 |
| 151～200 | N | 24.80 | 30.70 | 74.00 | 10.89 | 43.48 | 14.87 | 52.08 | 82.18 | 78.87 | 11.59 / 4.70 | 4.06 | 8.65 | 23.27 | 5.98 | 21.92 |
| | S | 25.60 | 31.4 | 73.87 | 11.09 | 43.08 | 13.39 | 51.30 | 80.80 | 79.51 | 12.7 / 3.79 | 5.10 | 8.97 | 23.23 | 5.98 | 18.45 |
| 201～250 | N | 34.00 | 39.7 | 99.20 | 14.2 | 56.89 | 18.37 | 68.37 | 96.33 | 100.85 | 16.34 / 5.00 | 6.13 | 12.34 | 32.95 | 7.76 | 30.0 |
| | S | 29.10 | 38.7 | 92.42 | 13.45 | 55.8 | 16.6 | 67.30 | 103.50 | 101.60 | 15.46 / 5.31 | 6.18 | 11.72 | 29.20 | 7.19 | 27.23 |
| 251～300 | N | 41.7 | 49.82 | 122.0 | 18.47 | 72.25 | 22.84 | 86.51 | 132.21 | 128.10 | 20.14 / 8.25 | 8.63 | 16.09 | 39.42 | 10.06 | 34.96 |
| | S | 41.8 | 49.4 | 122.6 | 16.40 | 70.95 | 21.15 | 84.32 | 129.05 | 127·85 | 19.00 / 7.43 | 8.42 | 15.71 | 39.00 | 9.64 | 34.90 |
| 301～350 | N | 52.2 | 61.5 | 149.2 | 18.34 | 90.75 | — | 105.81 | 164.08 | 164.45 | 22.35 / 11.00 | 9.41 | 20.31 | 47.82 | 12.99 | — |
| | S | 49.0 | 59.0 | 141.3 | 20.25 | 83.21 | 28.50 | 99.25 | 138.00 | 156.09 | 23.00 / 10.16 | 10.77 | 18.76 | 46.06 | 11.60 | 39.83 |
| 351～400 | N | 57.0 | 70.5 | 164.0 | 21.00 | 98.74 | 36.00 | 119.83 | 184.09 | 178.20 | 22.00 / 11.00 | 11.00 | 21.62 | 54.15 | 13.32 | 47.00 |
| | S | 56.0 | 66.4 | 157.8 | 23.50 | 95.51 | 28.21 | 116.00 | 178.80 | 172.20 | 23.41 / 10.50 | 11.75 | 23.01 | 53.90 | 13.90 | 43.85 |
| 401～450 | N | 75.0 | 87.0 | 203.5 | 25.00 | 125.00 | — | 145.00 | 226.50 | 219.50 | — / 20.5 | 15.25 | 29.5 | 64.5 | 16.50 | — |
| | S | 66.7 | 81.5 | 186.0 | 25.60 | 120.30 | 36.33 | 145.90 | 219.90 | 214.50 | 32.33 / 14.67 | 13.87 | 29.37 | 68.20 | 15.55 | 53.40 |
| 451～600 | N | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | S | 79.0 | 97.5 | 221.0 | 28.00 | 124.30 | 39.50 | 168.02 | 253.80 | 247.80 | 40.00 / 15.00 | 18.50 | 32.00 | 79.40 | 18.50 | 66.50 |

N: Northern Pacific fin whale foetuses S: Antarctic fin whale foetuses

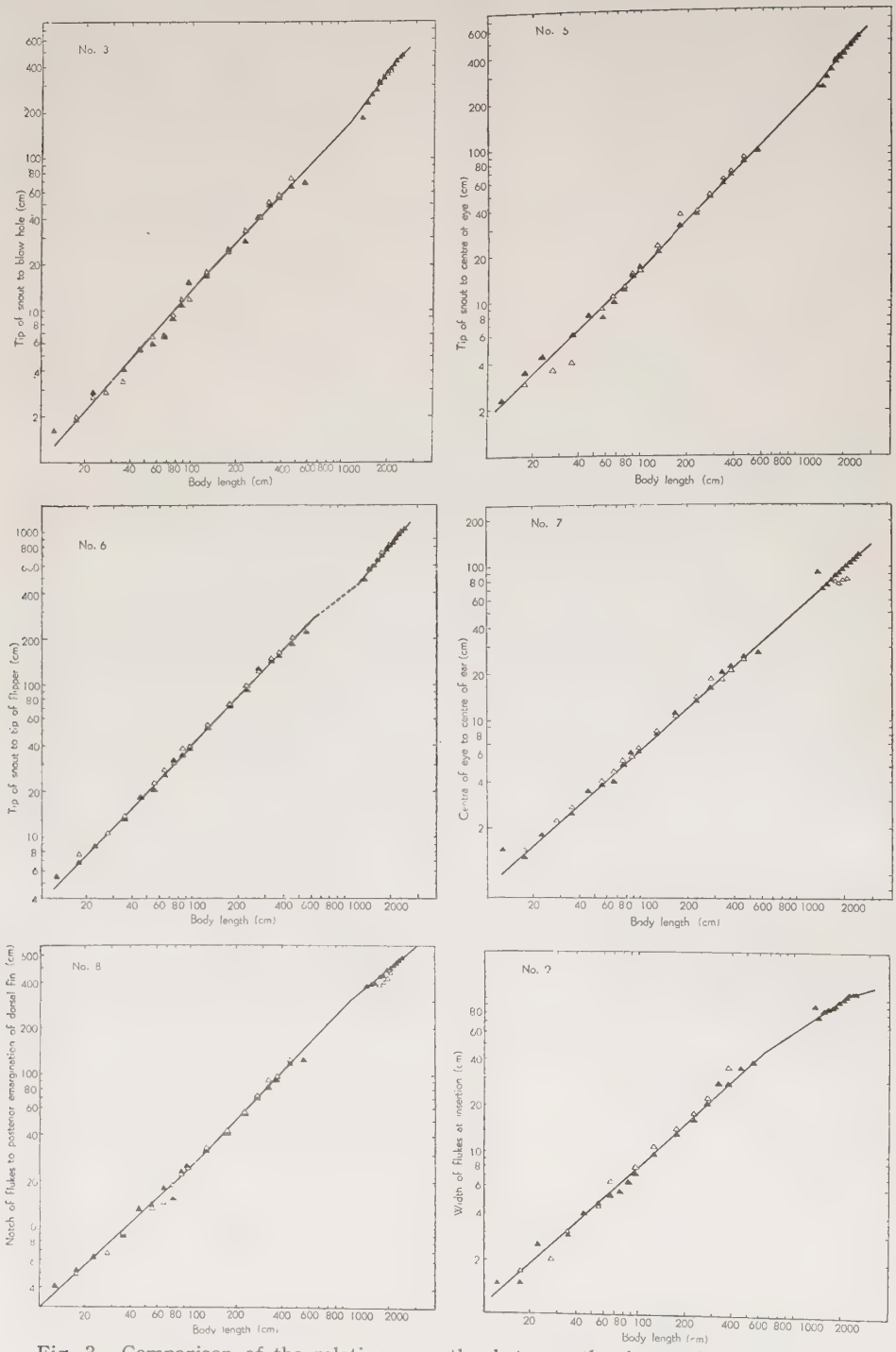

No. 3
Tip of snout to blow hole (cm)
Body length (cm)
No. 5
Tip of snout to centre of eye (cm)
Body length (cm)
No. 6
Tip of snout to tip of flipper (cm)
Body length (cm)
No. 7
Centre of eye to centre of ear (cm)
Body length (cm)
No. 8
Notch of flukes to posterior emargination of dorsal fin (cm)
Body length (cm)
No. 9
Width of flukes at insertion (cm)
Body length (cm)

Fig. 3. Comparison of the relative growths between the Antarctic and the North Pacific fin whales.

Closed triangle: Mean values of the Antarctic fin whales in each body length classes. Open triangle: Mean values of the North Pacific fin whales in each body length classes.

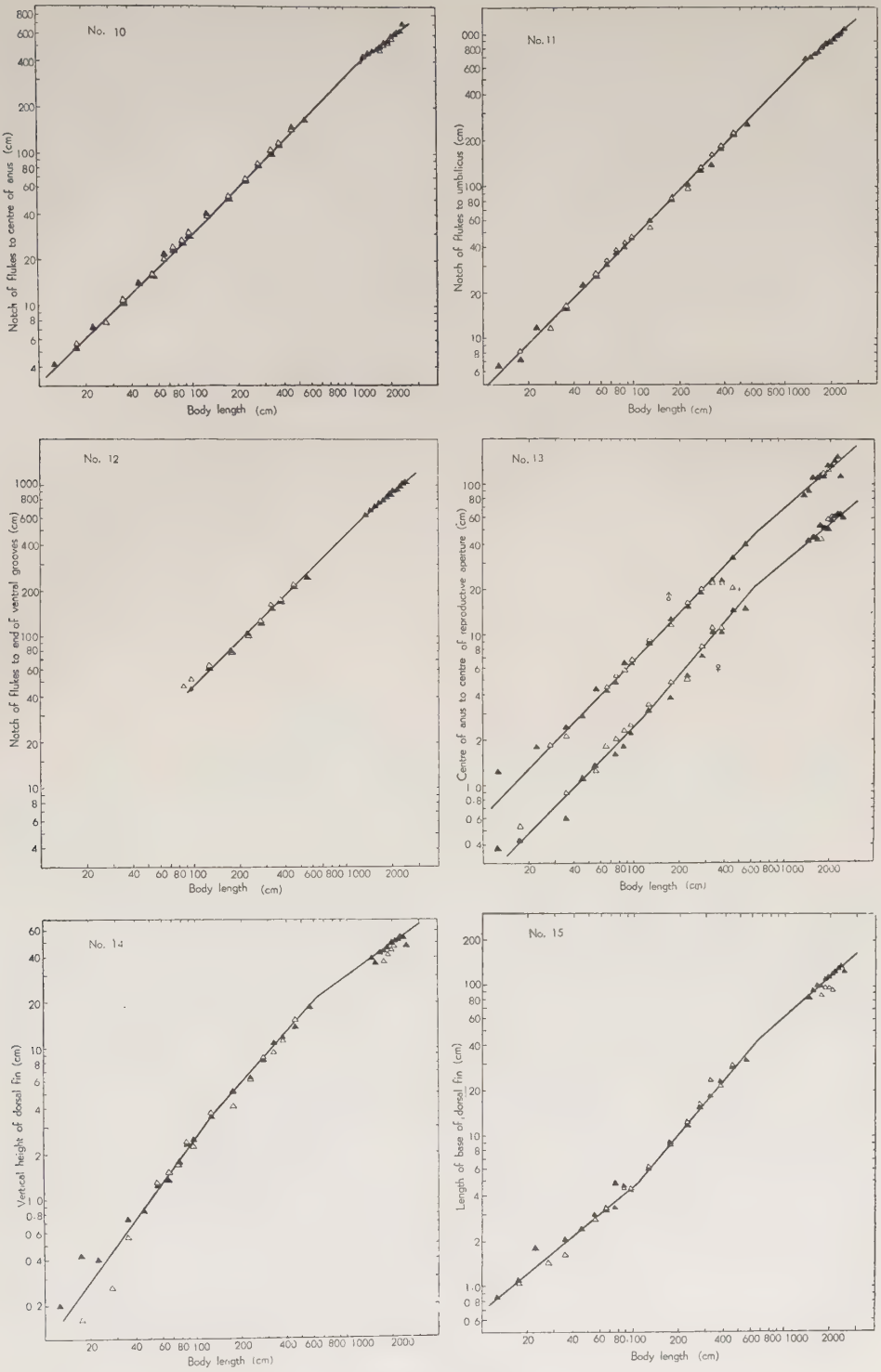

No. 10
Notch of flukes to centre of anus (cm)
Body length (cm)
No. 11
Notch of flukes to umbilicus (cm)
Body length (cm)
No. 12
Notch of flukes to end of ventral grooves (cm)
Body length (cm)
No. 13
Centre of anus to centre of reproductive aperture (cm)
Body length (cm)
No. 14
Vertical height of dorsal fin (cm)
Body length (cm)
No. 15
Length of base of dorsal fin (cm)
Body length (cm)

Fig. 3. (Cont.)

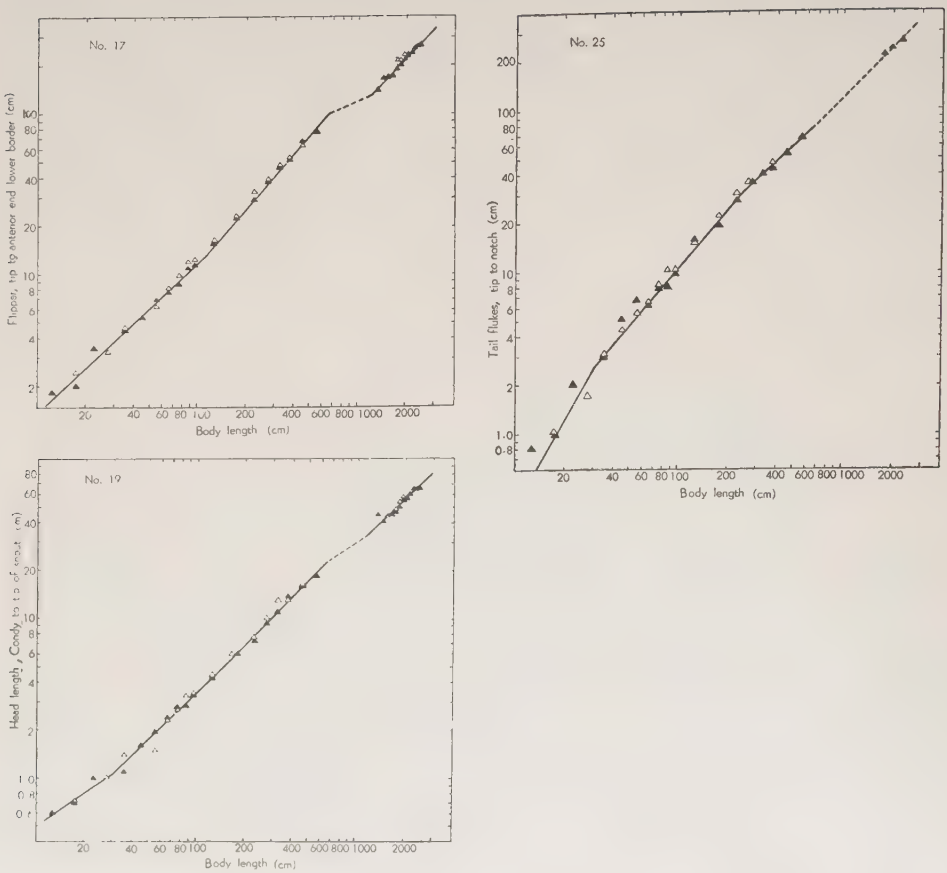

No. 17
Flipper, tip to anterior end lower border (cm)
Body length (cm)
No. 25
Tail flukes, tip to notch (cm)
Body length (cm)
No. 19
Head length, Condy to tip of snout (cm)
Body length (cm)

Fig. 3. (Cont.)

are not recognized between the Antarctic and the North Pacific fin whales at least in the foetal stage. Concerning on this subject, Ohsumi, Nishiwaki & Hibiya (1958) state that growth rate of foetuses for the northern Pacific fin whales is closely similar to that of other regions: coast of Japan, the North Atlantic and the Antarctic.

I may conclude that there is no racial difference in growth rates and external form of fin whales at least in the foetal stage.

For the relative growth of the adult stage between No. 1 and other measurements, the differences between two races are almost not recognized in the Nos. 3, 5, 6, 11, 12, 13 and 19. The differences are recognized in the relative growth between No. 1 and Nos. 7, 8, 10, 14, 15 and 17. Measurements Nos. 7, 8, 10, 14 and 15 of the North Pacific fin whales are smaller than those of the Antarctic fin whales in the same body length classes. And No. 17 of the former is larger than the latter. This will mean that the racial difference appears in the adult stage. It

seems to be concerned with the facts that the $\alpha$-values in the allometry formula of the measurement Nos. 7, 8, 10, 14 and 15 are smaller than 1.0, and the $\alpha$-value of the No. 17 is larger than 1.0, as calculated in the following paragraph. Meanwhile, considering the tendency that the parts which is different in the two races are variable by the habit as shown in Chapter 3, it will be recognized that the two races are different in these measurement parts.

## THE CRITICAL POINTS AND ITS RELATION TO THE GROWING STAGE OF THE FIN WHALE

As stated in the first paragraph, the relative growths of fin whales over 10 cm long have in general some critical points. The all external body parts do not grow in the same ratio, but change their rates of growth. Arranging the body length of critical points in these relative growths in Fig. 4, the body length of critical points are classified into six groups of 30 cm, 100-120 cm, 300 cm, 550-650 cm, 1,100-1,200 cm and 2,000-2,100 cm. The allometries which have a critical point in the body length of 30 cm are No. 1–No. 19, No. 1–No. 25 and No. 9–No. 25. And the allometries which have a critical point in the body length of 300 cm are No. 7–No. 25 and No. 9–No. 25. These groups are relatively few.

However, eleven allometries have a critical point in the body length of 100-120 cm, eleven allometry have a critical point in the body length of 550–650 cm, nine allometry have a critical point in the body length of 1,100-1,200 cm, and five examples have a critical point in the body length of 2,000–2,100 cm. No allometry has critical points in the other body length.

Co-ordinating the above results, most external parts of the fin whale change their allometries in the body length of 100–120 cm, 550–650 cm, 1,100-1,200 cm and 2,000-2,100 cm. And few parts change in the body length of 30 cm and 300 cm. Then, the relative growth of the external parts of the Antarctic fin whales over 10 cm long are classified in the following stages.

| | *Body length* |
|---|---|
| Ia-stage | 10～ 30 cm |
| Ib-stage | 30～ 115 cm |
| IIa-stage | 115～ 300 cm |
| IIb-stage | 300～ 650 cm |
| III-stage | 650～1,200 cm |
| IV-stage | 1,200～2,100 cm |
| V-stage | 2,100～ cm |

As it is considered that the morphological, physiological and ecological change have relation to the allometry, I examined the morphological

and ecophysiological changes in the growth of fin whale.

*Development of body colour*

Mackintosh & Wheeler (1929), Slijper (1958) and others report on the development of the body colour in the fin whales. In this paper, the development of colouration based on these reports and my observation are discussed. Pigment appears before the first stage of the development of ventral grooves. Before the foetus grows to be 40 cm long, it is present as a darkening of the skin on the top of head, left side of lower jaw and the posterior margin of the upper surface of flukes. Then the pigment appears in the skin of the posterior margin of the upper surface of flipper and the posterior margin of the dorsal fin. At this stage rest of the body are pinkuish red.

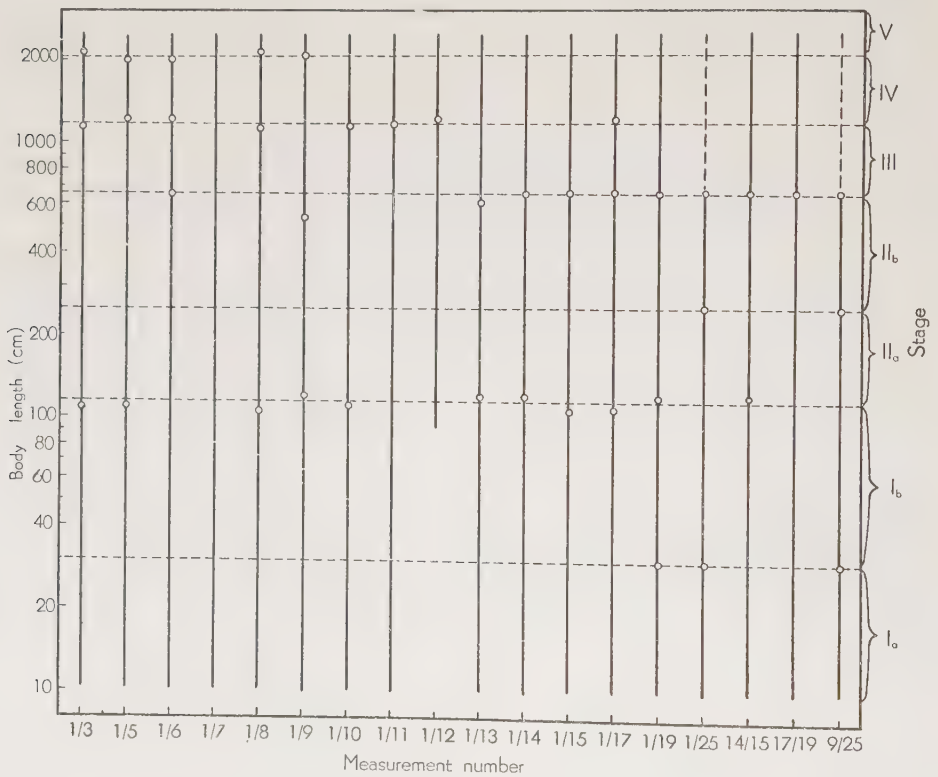



Fig. 4. Critical points and the stages of growth in the Antarctic fin whales. Open circle: critical point.

As the pigment spreads backward from the neck over the dorsal surface, the pale dorsal V-mark appears soon after growing to 1.0 m long. And soon it becomes even more prominent than in adult whale. The development of colouring spreads downwards over flanks. At 1.2 m the

lower jaw is well pigmented and the asymmetry of colouring is already distinguishable.

In the body side from umbilicus till anus, the pigmentation takes place relatively slowly in the body side from umbilicus till anus, and the back pigmentation appears lastly.

Table 4 shows the developmental stage of colouration and the individuals observed their body colour. I observed a 282 cm long individual of which the pigmentation was complete. And there was a 322 cm long foetus in which pigmentation was yet not complete.

TABLE 4. THE DEVELOPMENT OF BODY COLOUR

| Developement of body colour | Examples | Range |
|---|---|---|
| Not complete | 194 cm ♀, 212 cm ♂, 239 cm ♀ | ~239 cm |
| Almost complete | 222 cm ♀, 262 cm ♀, 265 cm ♂, 268 cm ♀, 294 cm ♀, 322 cm ♀ | 222~322 cm |
| Complete | 282 cm ♀, 307 cm ♀, 318 cm ♀ | 282~ cm |

TABLE 5. THE PROCESS OF DEVELOPMENT OF VENTRAL GROOVES AND THE BODY LENGTH IN THE ANTARCTIC FIN WHALE FOETUSES

| Stage | Examples | Range |
|---|---|---|
| Not appeared | 19.6 cm ♀, 35.7 cm ♀, 48 cm ♀, 50.5 cm ♀, 61 cm ♂, 70 cm ♀ | ~ 70 cm |
| Appeared at the axilla | 60.5 cm ♀, 73 cm ♀, 77 cm ♂ | 60~ 77 cm |
| Appeared at the lower jaw | 73.5 cm ♀, 83 cm ♀, 91.5 cm ♂, 96 cm ♀, 97 cm ♂ | 73~ 97 cm |
| Many furrows, but not yet joined | 91 cm ♀, 94.5 cm ♀, 102 cm ♂, 104 cm ♂, 107 cm ♀, 109 cm ♂, 110 cm ♀, 114 cm ♀, 116 cm ♀, 118 cm ♂ | 91~118 cm |
| Completed | 115 cm ♂, 127 cm ♂, 130 cm ♀, 132 cm ♀, 135 cm ♂, 141 cm ♀, 1353 cm ♀, 155 cm ♂ | 115~ cm |

It is recognized that 3.0 m is the mean body length which is complete in pigmentation. In the foetal stage, the colour is still rather paler than the adult.

In conclusion, the body lengths estimated as the developmental stages of the colouration are as follows:

40 cm : Appeared the pigmentation.
300 cm : Completed the colourations.
650 cm : Birth.

*Development of the ventral grooves*

The ventral grooves always end evenly near the umbilicus in the adult fin whales. On the development of the ventral grooves in the fin whale, Mackintosh & Wheeler (1929) state that the ventral grooves usually appear by the time the foetus reaches 1.0 m. Zemskiy (1950) also states that the ventral grooves appear in the 1.0 m long foetuses. In this stage it is difficult to observe the grooves. In the over 1.5 m long

foetuses, the grooves becomes distinctly similar to the adult.

According to my observation for the Antarctic fin whale foetuses, the ventral grooves is not appeared by the time the foetus reaches 60 cm long. They are appeared at the axilla in the foetuses from 60 cm till 80 cm long. As the foetuses grow, the sharrower furrows appeared in the axilla increase in the number and develop downward.

On the other hand, sharrow furrows are is appeared in the front of the lower jaw firstly in the 73 cm foetus. They are appeared firstly on the center in the front of lower jaw and increase in number along the anterior margin of lower jaw.

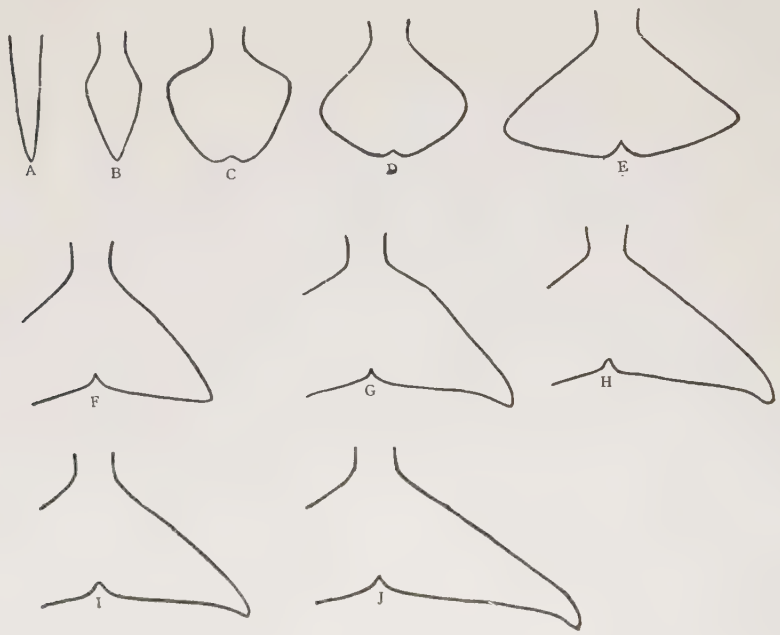



Fig. 5. Development of the tail flukes in fin whales.
A: 6.7 cm, B: 12.0 cm ♂, C: 17.9 cm ♀, D: 24.7 cm ♂,
E: 54.0 cm ♀, F: 69.3 cm ♂, G: 89.5 cm ♀, H: 214 cm ♀,
I: 527 cm ♀, J: 1920 cm ♀

In a word, the ventral grooves develop at the axilla and the front of lower jaw. They are appeared earlier and faster at the former than at the latter. The grooves appeared in the two parts increase in number and meanwhile spread downwards and backwards.

The furrows appeared in the two parts are not joined by the time foetuse reached in 115 cm. And the ventral grooves are completed by 140 cm. The grooves in the joined area are often show Y-shaped furrows.

Table 5 shows the body lengths in the process of development of

ventral grooves in the Antarctic fin whale foetuses. In conclusion, the body lengths considered as the developmental stages of the ventral grooves are as follows:

60– 80 cm: present the furrows
115–140 cm: complete the ventral groove

*Development of the flukes*

One of the characteristic development of whales is the tail flukes. Fig. 5 shows the developmental stages of theAntarctic fin whales. Before the time when foetus reaches 8 cm long, the tip of tail is merely conical. But by the time when they grow to 10 cm long, the projection of skin is present on the side of tail. As development goes by the projection changes its shape. By the time when the foetuses grow to 80 cm long, the shapes of flukes become similar to the adult stage.

TABLE 6. DEVELOPMENTAL STAGES OF BALEEN PLATES IN THE ANTARCTIC FIN WHALE FOETUS

| Stage | Examples (Body length in cm) | Range of body length |
|---|---|---|
| I | ♀ 91, ♂ 109, ♂ 112, ♂ 116, ♀ 122, ♀ 153, ♂ 155, ♀ 157, ♀ 166, ♀ 172 | ~175 cm |
| II | ♀ 177, ♂ 212, ♀ 215, ♂ 219, ♂ 239, ♀ 251 | 175~260 cm |
| III | ♀ 262, ♀ 282, ♀ 294, ♂ 297, ♀ 307, ♂ 315 | 260~315 cm |
| IV | ♀ 318, ♀ 322, ♂ 354, ♂ 358, ♂ 361, ♀ 361, ♂ 377, ♀ 427, ♀ 431 | 315~430 cm |
| V | ♀ 441, ♀ 447, ♀ 488, ♀ 495, ♀ 527 | 430~650 cm |

The distinctive feature in the foetal stage is that the flukes are folded ventrally at insertion. In the development of tail flukes the body lengths considered as the critical stage are as follows:

9 cm: Projection appears
80 cm: Shape is almost complete
650 cm: Birth

*Development of the baleen plates*

The first rudiments of the plates are found after the fin whale foetus reaches to the length of 175 cm. Their plain strip of a soft whitish material appears. In this condition, rudimental teeth are still burried in the cavity of maxilla. The strip grows in thickness and in the foetuses between 260 cm and 315 cm, the rudimentary teeth are absorbed, the cavity becomes flat over 315 cm. Minute transverse ridges appear on this strip and later develop into baleen plates. The terminal bristles of baleen plates appear after foetus reaches to the length of 430 cm. Table 6 shows the classification of the developmental stages of baleen plates. In I-stage, rudiments of plates do not found yet. The plain strip appears in II-stage. In the III-stage, the rudimental teeth are absorbed.

IV-stage is recognized as the time when ridges appear on the strip. In V-stage bristles appear on the tip of baleen plates. According to Mackintosh & Wheeler (1929), rate of growth in baleen plates suddenly increases when the whale measures about 13 m. In short, the body lengths estimated as the remarkable stages in the development of baleen plates are as follows:

175 cm: Rudiments of baleen plates appear
260–315 cm: Rudimental teeth are absorbed
430 cm: Bristles appear on the top of baleen plates
1300 cm: Baleen plates suddenly increase in length

*Body length at birth*

Laws (1959) reviews the previous papers on the growth of foetuses in the whales. I picked up the body length at birth of fin whales in the previous papers. Hinton (1925) describes that in the southern fin whales, body length at birth is to be 610 cm. Mackintosh & Wheeler (1929) and Laws (1959) state that the mean lengths at birth are estimated to be 6.5 m for the southern fin whales.

Ohsumi, Nishiwaki & Hibiya (1958) describe that growth rate of foetuses for the northern Pacific fin whale is closely similar to that of other regions:—Coast of Japan, the North Atlantic and the Antarctic. And they estimate that the mean body lengths at birth is supposed to be 21 feet (6.4 m). It will be summarized that foetal growth rates of fin whales in the both hemispheres are closely similar one another, and the mean lengths at birth are about 6.5 m.

Kimura (1957) reports the twinning of fin whale foetuses and suggests that the difference of body lengths will be 2 feet (60 cm) long at birth, and in the foetal stage, there is no sex difference in the rate of foetal growth.

*Body length at weaning*

The knowledge on the weaning of fin whales has been scanty. According to the paper by Mackintosh & Wheeler (1929), nursing period is estimated six months and the body length at weaning is 12 m for the southern fin whales.

The humpback whales in the Australian waters have been studied most in the baleen whales on the weaning. Chittleborough (1958) reports that the nursing period is $10\frac{1}{2}$ months and the body length at weaning is estimated to be about 29 feet. The body length at birth is recognized as 14 feet (Chittleborough, 1958), so the length at weaning correspond to twice of the length at birth. If the ratio is able to be adopted on *Balaenoptera*, the body length at weaning will be about 13 m (6.5 m × 2) for the fin whales. This value is similar to that by Mackintosh &

Wheeler (1929). Tavolga and Essapian (1955) report that in *Trusiopus truncatus* which are fed in a aquarium, the weaning period is not so distinct, and there are some periods when they eat fishes and drink milk.

*Body length at sexual maturity*

By the time at sexual maturity, body lengths of fin whales become to be different in the sexes and the races. Mackintosh (1942) calculates the body lengths at sexual maturity and describes that they are 19.2 m in males and 19.9 m in females for the southern fin whales.

Ohsumi, Nishiwaki & Hibiya (1958) report that in the fin whales from the northern parts of the North Pacific the sexual maturity attains at 58 feet (17.7 m) in males and 61 feet (18.6 m) in females. On the fin whales from the East China Sea which are recognized as one of the independent races in the North Pacific, the body length at sexual maturity is estimated to be 56 feet (17.1 m) in males and 59 feet (18.0 m) in females respectively.

*Body length at physical maturity*

On the southern fin whales, Mackintosh & Wheeler (1929) report that the body lengths at physical maturity are 21.0 m in males and 22.0 m in females. Nishiwaki (1952) gets the similar result.

Ohsumi, Nishiwaki & Hibiya (1958) describe that the average length at physical maturity is 62 feet (18.9 m) in males and 66 feet (20.1 m) in female fin whales from the the northern Pacific. The physical maturity is determined by the completion of the occification of vertebral column (Wheeler, 1930). However, Fujino (1954) states that the skull grows after the so called physical maturity.

Summarizing the above results and the discussing the relation between the critical points in the allometry formula and the stage of growth in the Antartic fin whales, the following relations are obtained :

30 cm : The first stage of the development of body colour.
115 cm : Completion of the development in the ventral grooves.
300 cm : Absorption of rudimental teeth, completion of development of body colour in the foetal stage.
650 cm : Birth.
1,200 cm : Weaning.
2,100 cm : Sexual maturity—Physical maturity.

As stated in the previous paragraphs, the most allometries change in the body lengths of 115, 650, 1,200 and 2,100 cm. These body lengths are important for the embriology and ecology of the fin whales. Body length of 115 cm which is the end of the I-stage is correspond to the

time of completion of development of the ventral grooves, and in this stage, the development of the outer style is almost complete. 650 cm is correspond to the body length at birth. After that time fin whales change in their ecology. They must swim just after birth. Therefore, the parts for swimming should change in their shapes. In fact, the body portion which have the critical point in this body length are measurement Nos. 6, 9, 14, 15, 17, 19 and 25. These portions are all concerned with the swimming. However, although No. 13 is not concerned directly for the purpose, this measurement changes its allometry in the body length. The body length of 1,200c m is correspond to the weaning period. Food habit of fin whale changes bordering the period, measurement Nos. 3 and 5 of which allometries have critical point in this body length are concerned in the shape of month. No. 12 is concerned in the length of ventral grooves. Nemoto (1959) records the relation between food habit and the ventral grooves. Nos. 6, 8, 10 and 17 are concerned in the movement of whales. It is considerable to change the movement according to the change of food habit.

2,100 cm is the body length at maturity. It will be considered that the whale body change for adaptation of movement and feeding because the body length approach to the maximum. Nos. 3 and 5 are concerned in the feeding, and Nos. 6, 8, and 9 are concerned in the movement. These measurement have critical point in the body length.

## ALLOMETRY FORMULA AND $\alpha$-VALUE

In the allometry formula: $y=b\chi^{\alpha}$, $b$ equals to $y$ when $x=1$. And $b$ is influenced by the first quantity of $y$. Symbol $b$ is named as the "initial growth index". Symbol $\alpha$ shows the relation between the growths of the two portions ($x$ and $y$) and is named as "relative growth coefficient". That is to say, $\alpha$ shows the specific growth rate between the two portions.

Symbol $\alpha$ is more important biologically than $b$. Except the monophasic allometry, we consider that $b$ has not any biological meaning.

The meaning of the $\alpha$-value is as follows:

1. $\alpha>1.0$. It means that growth of $y$ exceeds that of $x$. This allometry is named *possitive allometry*.
2. $\alpha=1.0$. $y$ and $x$ grow in the name rate. This is named as *isometry*.
3. $\alpha<1.0$. It means that growth of $y$ is inferior to that of $x$, and named *negative allometry*. Negative allometry includes the following three cases.
   i. $0<\alpha<1.0$
   ii. $\alpha=0$ Although $x$ grows, $y$ stands still.

iii. $\alpha<0$ Although $x$ grows, $y$ decreases absolutely.

In the allometry of the external form in fin whales, there is no example as 3ii or 3iii. However, according to the paper by Matthews (1937) in the allometry formula of humpback whales between No. 1 and No. 13, $\alpha$-value of adult females is $-0.60(\alpha<0)$. Table 7 shows the $\alpha$-value in the each stages of the allometry between No. 1 and various measure-in ments.

TABLE 7. $\alpha$-VALUES IN THE ALLOMETRY FOR MULLA FOR THE ANTARCTIC FIN WHALES

| Measurement No. | Stage | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | I $a$ | I $b$ | II $a$ | II $b$ | III | IV | V | |
| 3 | 1.13 | 1.13 | 1.05 | 1.05 | 1.05 | 1.41 | 0.94 | 1.11 |
| 5 | 0.97 | 0.97 | 1.05 | 1.05 | 1.05 | 1.36 | 0.85 | 1.04 |
| 6 | 1.04 | 1.04 | 1.04 | 1.04 | 0.83 | 1.13 | 1.02 | 1.02 |
| 7 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | ..90 | 0.90 | 0.90 |
| 8 | 0.93 | 0.93 | 1.04 | 1.04 | 1.04 | 0.85 | 0.65 | 0.93 |
| 9 | 0.89 | 0.89 | 1.07 | 1.07 | 0160 | 0.60 | 0.31 | 0.78 |
| 10 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 0.83 | 0.83 | 0.95 |
| 11 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 0.86 | 0.86 | 0.97 |
| 12 | — | — | 1.01 | 1.01 | 1.01 | 0.82 | 0.82 | 0.93 |
| 13 ♂ | 1.03 | 1.03 | 1.07 | 1.07 | 0.87 | 0.87 | 0.87 | 0.97 |
| 13 ♀ | 1.02 | 1.02 | 1.20 | 1.02 | 0.82 | 0.82 | 0.82 | 0.97 |
| 14 | 1.29 | 1.29 | 1.16 | 1.16 | 0.72 | 0.72 | 0.72 | 1.01 |
| 15 | 0.82 | 0.82 | 1.16 | 1.16 | 0.86 | 0.86 | 0.86 | 0.93 |
| 17 | 0.96 | 0.96 | 1.13 | 1.13 | 0.44 | 1.04 | 1.04 | 0.96 |
| 19 | 0.68 | 0.96 | 1.02 | 1.02 | 0.65 | 0.98 | 0.98 | 0.90 |
| 25 | 1.85 | 1.18 | 1.18 | 1.14 | 1.02 | 1.02 | 1.02 | 1.20 |

TABLE 8. RANGE OF $\alpha$-VALUES IN THE GROWING STAGE

| | Stage | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | I $a$ | I $b$ | II $a$ | II $b$ | III | IV | V | |
| 0.31~0.40 | — | — | — | — | — | — | 1 | 1 |
| 0.41~0.50 | — | — | — | — | 1 | — | — | 1 |
| 0.51~0.60 | — | — | — | — | 1 | 1 | — | 2 |
| 0.61~0.70 | 1 | — | — | — | 1 | — | 1 | 3 |
| 0.71~0.80 | — | — | — | — | 1 | 1 | 1 | 3 |
| 0.81~0.90 | 3 | 3 | 1 | 1 | 5 | 8 | 8 | 39 |
| 0.91~1.00 | 4 | 5 | 1 | 1 | 1 | 1 | 2 | 15 |
| 1.01~1.01 | 4 | 4 | 9 | 9 | 6 | 2 | 3 | 37 |
| 1.11~1.20 | 1 | 2 | 5 | 5 | — | 1 | — | 14 |
| 1.21~1.30 | 1 | 1 | — | — | — | — | — | 2 |
| 1.31~1.40 | — | — | — | — | — | 1 | — | 1 |
| 1.41~1.50 | — | — | — | — | — | 1 | — | 1 |
| 1.51~1.60 | — | — | — | — | — | — | — | — |
| 1.61~1.70 | — | — | — | — | — | — | — | — |
| 1.71~1.81 | — | — | — | — | — | — | — | — |
| 1.81~1.90 | 1 | — | — | — | — | — | — | 1 |
| Total | 15 | 15 | 16 | 16 | 16 | 16 | 16 | 110 |
| Mean | 1.04 | 1.01 | 1.07 | 1.07 | 0.87 | 0.94 | 0.91 | 0.97 |

The highest $\alpha$-value is given in the Ia-stage of the allometry between No. 1 and No. 25, and it is 1.85. On the contrary, the lowest is given in the V-stage of the allometry between No. 1 and No. 9 ($\alpha=0.31$).

Most of $\alpha$-values are included in the range between 0.81 and 1.20. So, the range is very narrow. $\alpha$-value seems to vary according to the growing stages. The frequencies of $\alpha$-value of 16 measurements are given in Table 8. The average $\alpha$-values in each stages are maximum II-stage and minium in V-stage.

Arranging the measurements from anterior to posterior Nos. 3, 5, 6, 11, 10, 8, and 9, and the $\alpha$-values of each measurements are connected in five stages (Fig. 6). In II-stage, $\alpha$-values are not so different each other, but in IV- and V-stage, there are difference of $\alpha$-values between anterior portions and posterior portions, and $\alpha$-values are higher in the anterior than in the posterior. Similar phenomena are shown in I-stage, but the tendency is not so remarkable as in IV- and V-stage. In III-stage, the $\alpha$-values of Nos. 6, 11 and 9 are relatively lower than the others.

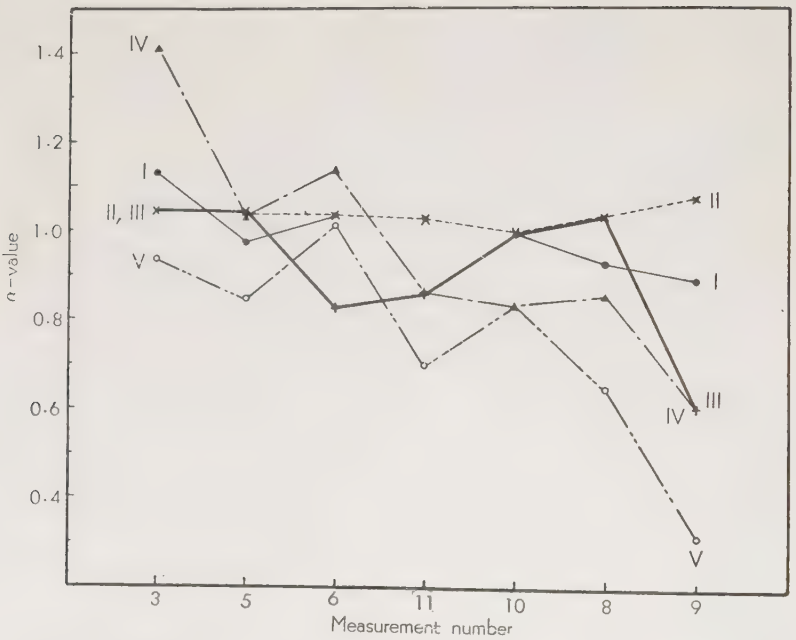



Fig. 6. Variation of $\alpha$-values in five stages for measurement numbers 3, 5, 6, 11, 10, 8 and 9.

Averaging the $\alpha$-values of each measurement among the all stages, the averages decrease in order from anterior to posterior.

Fig. 7 shows the variation of $\alpha$-values of each measurement in the five stages.

1. $\alpha$-value is maximum in I-stage and decrease in order.
   i) Nos. 10, 11 and 12: Until the III-stage, the allometry is almost isometry, but then turns negative allometry.

ii) No. 14: The allometry shows positive allometry till the II-stage. Moreover, $\alpha$-value in I-stage is larger than II-stage.

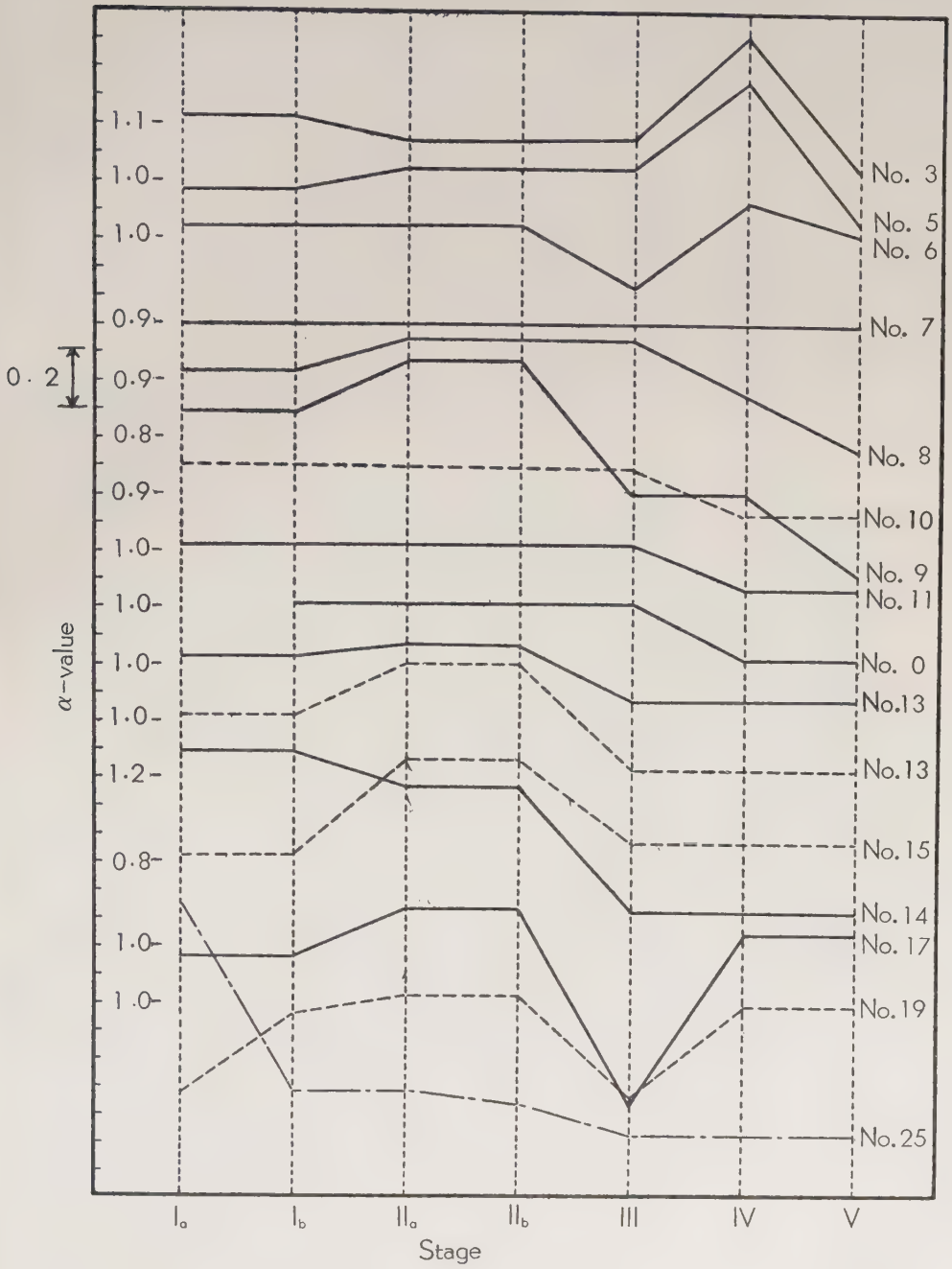



Fig. 7. Variation of $\alpha$-values of each measurements according to the growing stages.

However, after than it shows negative allometry.

iii) No. 25 : The allometry shows the decreasing positive allometry until II-stage. After then, it shows isometry.

2. The parts of which $\alpha$-value increase as time goes by.

There is not in fin whales.

3. $\alpha$-values are high in younger stage, then decrease in some time and again increase.

iv) No. 17 : Negative allomety in I-stage. Isometry in II-stage, $\alpha$-value decrease suddenly after IV-stage, it becomes again positive allometry.

v) No. 19 : Negative allometry in I-stage, isometry in II-stage, in III-stage suddenly decrease. After then it becomes again isometry.

4. Reverse growth to the above (3).

vi) No. 5 : In I-stage, it shows the negative allometry near the isometry ($\alpha=0.97$), but in II-, III- and IV-stages it becomes positive allometry. Especially, $\alpha$-value in IV- stage is very high ($\alpha=1.36$). In V-stage it becomes again negative allometry.

vii) No. 8 : Negative allometry in I-stage. Positive in II- and III-stage. Negative in IV- and V-stage.

viii) No. 9 : Negative allometry in I-stage, positive in II-stage. After III-stage, it shows negative allometry, and $\alpha$-value decrease remarkably.

ix) No. 13 : $\alpha$-value of females is different to that of males. But the tendencies are similar each other. Nearly isometry in I-stage. Positive in II-stage. After then it becomes negative allometry.

x) No. 15 : Positive allometry in II-stage. But negative in I-III- and V-stages.

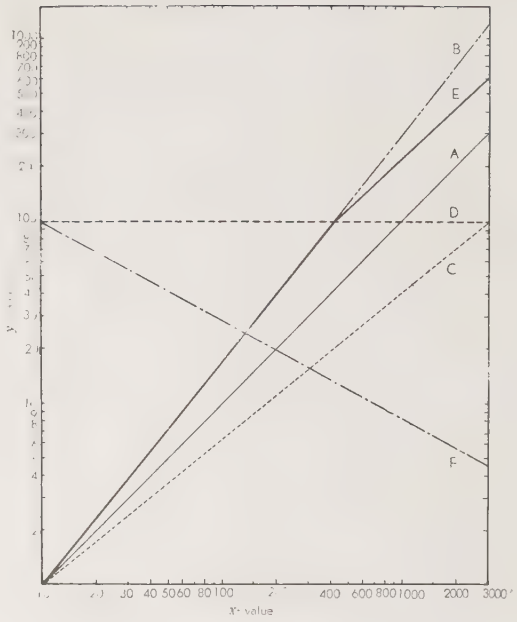
5. Almost constant allometry throughout the growing stages.

xi) No. 7 : Negative allometry ($\alpha=0.90$) throughout all stages.

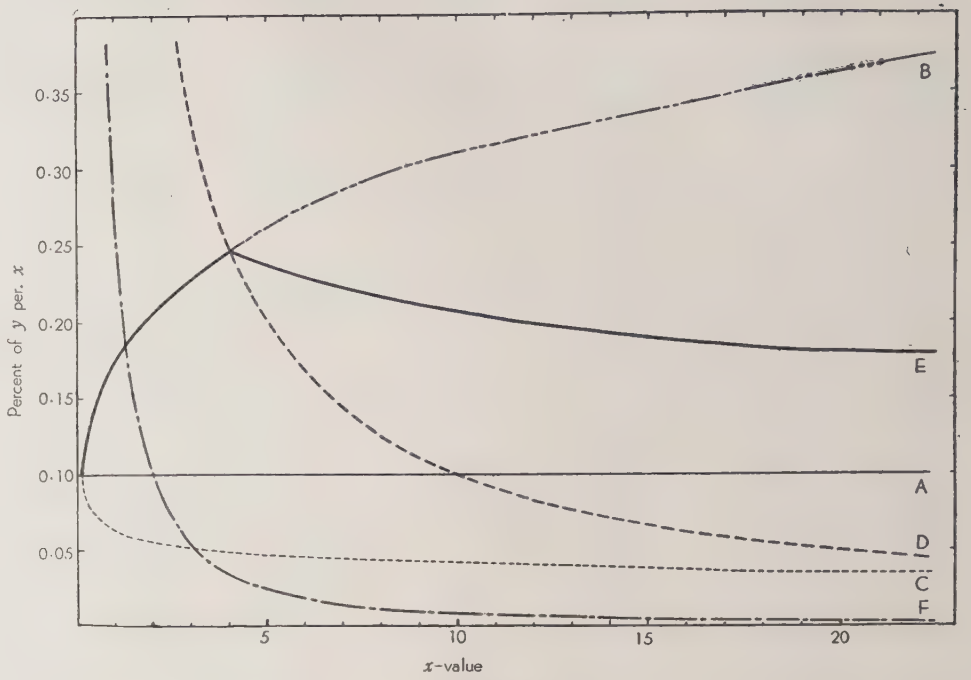
6. Complicated allometry.

xii) No. 3 : Although it shows the positive allometry from I-stage till IV-stage, $\alpha$-values are low in the stages of II and III. And $\alpha$-value increases suddenly. It become negative allometry in V-stage.

xiii) No. 6 : $\alpha$-value is constant until II-stage and it shows positive allometry. However it becomes negative allometry in III-stage. In IV-stage it becomes again positive allometry, after then $\alpha$-value decreases in V-stage and becomes isometry.




a. Allometry




b. Proportion

Fig. 8. Relation between the allometry and proportion.
A: $\alpha=1.0$, B: $\alpha=1.25$, C: $\alpha=0.80$, D: $\alpha=0$,
E: $\alpha=1.25$ (untill $x=420$) and $\alpha=0.80$ (after $x=420$),
F: $\alpha=-0.50$

TABLE 9. MEAN VALUES OF THE BODY PROPORTIONS IN EACH BODY LENGTHCLASSES FOR THE FIN WHALE FOETUSES

| Body length classes (cm) | Sex | No. 3 (%) | No. 5 (%) | No. 6 (%) | No. 7 (%) | No. 8 (%) | No. 9 (%) | No. 10 (%) | No. 11 (%) | No. 12 (%) | No. 13 (%) | No. 14 (%) | No. 15 (%) | No. 17 (%) | Nc. 19 (%) | No. 25 (%) | No. 25 /No. 9 | No. 14 /No. 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10～25 | ♀ | 11.1 | 17.3 | 41.0 | 8.0 | 26.2 | 9.3 | 30.6 | 45.6 | — | 2.8 (5) | 0.97 | 6.1 | 13.2 | 4.3 | — | — | — |
| | ♂ | 9.7 | 16.9 | 41.4 | 7.1 | 26.1 | 10.5 | 28.1 | 44.5 | — | 5.8 (4) | 0.80 | 6.4 | 13.5 | 4.2 | — | — | — |
| | Total no. | 10 | 10 | 8 | 9 | 6 | 6 | 9 | 9 | — | | 9 | 9 | 9 | 8 | — | — | — |
| | Mean | 10.5 | 17.1 | 41.2 | 7.7 | 26.2 | 9.7 | 29.5 | 45.3 | — | | 0.91 | 6.2 | 13.3 | 4.3 | — | — | — |
| 26～50 | ♀ | 10.7 | 16.7 | 39.0 | 7.7 | 27.4 | 8.7 | 31.7 | 48.2 | — | 2.4 (7) | 1.7 | 5.2 | 12.3 | 3.4 | 8.8 | 1.02 | 0.31 |
| | ♂ | 11.7 | 17.8 | 39.9 | 7.7 | 26.3 | 8.5 | 29.2 | 47.1 | — | 6.7 (7) | 1.4 | 5.4 | 12.5 | 3.7 | 9.2 | 1.02 | 0.35 |
| | Total no. | 10 | 12 | 15 | 9 | 14 | 11 | 13 | 12 | — | | 10 | 13 | 9 | 14 | 11 | 9 | 11 |
| | Mean | 11.2 | 17.1 | 39.5 | 7.7 | 26.7 | 8.6 | 30.6 | 47.7 | — | | 1.6 | 5.3 | 12.4 | 3.5 | 9.0 | 1.02 | 0.33 |
| 51～75 | ♀ | 12.3 | 17.0 | 41.0 | 7.0 | 25.4 | 8.5 | 30.7 | 47.8 | — | 2.4 (7) | 2.5 | 5.2 | 12.0 | 3.7 | 10.7 | 1.12 | 0.47 |
| | ♂ | 12.7 | 16.0 | 40.5 | 6.94 | 26.6 | 8.7 | 31.2 | 48.4 | — | 6.7 (13) | 2.2 | 5.0 | 12.4 | 3.5 | 10.1 | 1.13 | 0.45 |
| | Total no. | 22 | 23 | 21 | 13 | 21 | 12 | 22 | 22 | — | | 20 | 22 | 22 | 20 | 17 | 11 | 21 |
| | Mean | 11.9 | 16.3 | 40.7 | 7.0 | 26.2 | 8.6 | 31.0 | 48.3 | — | | 2.3 | 5.1 | 12.2 | 3.6 | 10.2 | 1.16 | 0.46 |
| 76～100 | ♀ | 12.8 | 17.5 | 40.9 | 7.2 | 25.6 | 8.3 | 31.1 | 48.0 | — | 2.5 (12) | 2.4 | 4.8 | 13.0 | 3.6 | 10.7 | 1.30 | 0.52 |
| | ♂ | 13.1 | 17.2 | 40.3 | 6.8 | 25.8 | 8.0 | 360. | 48.2 | — | 6.7 (12) | 2.6 | 4.8 | 12.5 | 3.4 | 10.2 | 1.24 | 0.49 |
| | Total no. | 25 | 25 | 26 | 17 | 27 | 11 | 24 | 26 | — | | 25 | 20 | 24 | 25 | 18 | 10 | 24 |
| | Mean | 13.0 | 17.3 | 40.6 | 7.0 | 25.7 | 8.1 | 30.8 | 48.2 | — | | 2.5 | 4.8 | 12.8 | 3.5 | 10.5 | 1.27 | 0.51 |
| 101～125 | ♀ | 14.4 | 17.8 | 42.3 | 7.0 | 25.2 | 8.9 | 30.5 | 47.4 | 48.2 | 2.6 (10) | 2.9 | 5.0 | 13.1 | 3.3 | 10.6 | 1.30 | 0.56 |
| | ♂ | 13.3 | 16.7 | 42.3 | 1.9 | 25.0 | 8.5 | 30.2 | 47.3 | 51.5 | 6.5 (10) | 2.8 | 4.5 | 13.6 | 3.3 | 11.1 | 1.28 | 0.56 |
| | Total no. | 20 | 20 | 18 | 17 | 20 | 10 | 20 | 19 | 10 | | 18 | 19 | 18 | 18 | 13 | 12 | 18 |
| | Mean | 13.9 | 17.4 | 42.3 | 6.9 | 25.1 | 8.6 | 30.3 | 47.4 | 49.8 | | 2.8 | 4.8 | 13.4 | 3.3 | 10.9 | 1.29 | 0.56 |
| 126～150 | ♀ | 14.3 | 18.1 | 42.1 | 6.8 | 26.0 | 8.7 | 30.7 | 46.1 | 47.7 | 2.6 (15) | 2.8 | 4.7 | 13.3 | 3.3 | 11.5 | 1.35 | 0.59 |
| | ♂ | 14.1 | 17.7 | 42.0 | 6.8 | 25.3 | 9.2 | 29.8 | 47.1 | 48.2 | 7.2 (11) | 2.9 | 4.7 | 13.2 | 3.4 | 11.4 | 1.22 | 0.60 |
| | Total no. | 26 | 26 | 25 | 20 | 24 | 7 | 27 | 24 | 21 | | 25 | 24 | 22 | 24 | 15 | 7 | 23 |
| | Mean | 14.2 | 17.9 | 42.1 | 6.8 | 25.8 | 8.8 | 30.3 | 46.5 | 47.9 | | 2.8 | 4.7 | 13.3 | 3.3 | 11.5 | 1.35 | 0.59 |
| 151～200 | ♀ | 14.8 | 18.1 | 42.8 | 6.4 | 26.6 | 3.4 | 30.6 | 46.8 | 45.8 | 2.6 (23) | 2.8 | 5.0 | 13.6 | 3.5 | 12.1 | 1.41 | 0.53 |
| | ♂ | 14.4 | 17.9 | 42.4 | 6.6 | 24.9 | 8.2 | 30.0 | 47.1 | 46.8 | 6.8 (16) | 2.6 | 5.2 | 13.5 | 3.4 | 11.8 | 1.41 | 0.53 |
| | Total no. | 43 | 43 | 41 | 31 | 42 | 25 | 42 | 41 | 35 | | 43 | 41 | 36 | 31 | 31 | 25 | 40 |
| | Mean | 14.6 | 18.0 | 42.6 | 6.5 | 25.8 | 8.3 | 30.4 | 47.0 | 46.3 | | 2.7 | 2.7 | 13.6 | 12.0 | 12.0 | 1.41 | 0.53 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 201～250 | 우 | 14.5 | 18.0 | 43.0 | 6.3 | 25.7 | 8.2 | 30.9 | 47.3 | 46.3 | 2.5 (12) | 2.9 | 5.7 | 13.5 | 3.4 | 12.7 | 1.57 | 0.52 |
| | 수 | 14.7 | 17.9 | 43.0 | 6.1 | 25.4 | 8.2 | 30.0 | 47.2 | 45.8 | 7.1 (7) | 2.8 | 5.3 | 13.9 | 3.4 | 12.0 | 1.46 | 0.52 |
| | Total no. | 19 | 19 | 18 | 14 | 18 | 12 | 22 | 19 | 16 | | 18 | 18 | 16 | 18 | 14 | 11 | 18 |
| | Mean | 14.6 | 17.9 | 43.0 | 6.2 | 25.6 | 8.2 | 30.5 | 47.3 | 46.1 | | 2.8 | 5.4 | 13.7 | 3.4 | 12.4 | 1.52 | 0.52 |
| 251～300 | 우 | 15.1 | 17.8 | 42.8 | 6.1 | 25.6 | 8.0 | 30.5 | 46.8 | 45.3 | 2.8 (11) | 3.0 | 5.7 | 14.1 | 3.5 | 12.5 | 1.59 | 0.52 |
| | 수 | 15.4 | 17.6 | 43.3 | 6.0 | 25.6 | 8.4 | 31.0 | 48.3 | 47.1 | 7.1 (14) | 3.2 | 5.8 | 14.1 | 3.6 | 12.7 | 1.49 | 0.56 |
| | Total no. | 23 | 25 | 24 | 21 | 23 | 17 | 21 | 22 | 18 | | 22 | 23 | 21 | 22 | 18 | 16 | 23 |
| | Mean | 15.3 | 17.7 | 43.2 | 6.0 | 25.6 | 8.2 | 30.8 | 47.3 | 46.2 | | 3.1 | 5.8 | 14.1 | 3.6 | 12.6 | 1.53 | 00.4 |
| 301～350 | 우 | 15.6 | 18.2 | 43.5 | 6.0 | 26.2 | 8.1 | 30.8 | 48.5 | 48.1 | 3.3 (8) | 3.1 | 5.9 | 14.6 | 3.6 | 12.8 | 1.55 | 0.55 |
| | 수 | 15.5 | 19.0 | 44.9 | 6.1 | 26.5 | — | 32.5 | 47.7 | 49.4 | 6.9 (4) | 3.1 | 6.3 | 14.2 | 3.7 | 11.9 | — | 0.52 |
| | Total no. | 13 | 13 | 11 | 7 | 13 | 5 | 11 | 11 | 10 | | 14 | 13 | 12 | 11 | 8 | 5 | 13 |
| | Mean | 15.6 | 18.5 | 44.1 | 6.1 | 26.3 | 8.1 | 31.3 | 48.2 | 48.4 | | 3.1 | 6.0 | 14.4 | 3.6 | 12.6 | 1.55 | 0.54 |
| 351～400 | 우 | 14.8 | 17.6 | 43.0 | 5.9 | 25.9 | 9.4 | 32.4 | 49.2 | 47.5 | 2.8 (4) | 3.2 | 6.4 | 14.5 | 3.6 | 12.7 | 1.37 | 0.51 |
| | 수 | 15.5 | 18.5 | 43.0 | 5.8 | 26.3 | 8.5 | 32.0 | 48.0 | 47.5 | 6.8 (7) | 3.3 | 6.0 | 14.7 | 3.5 | 11.6 | 1.40 | 0.48 |
| | Total no. | 12 | 12 | 12 | 9 | 11 | 6 | 11 | 12 | 9 | | 10 | 12 | 11 | 11 | 8 | 6 | 11 |
| | Mean | 15.2 | 18.0 | 43.0 | 5.8 | 26.1 | 8.8 | 32.1 | 48.6 | 47.5 | | 3.2 | 3.2 | 14.6 | 3.5 | 12.0 | 1.38 | 0.49 |
| 401～450 | 우 | 15.2 | 18.6 | 42.4 | 5.8 | 27.0 | 8.3 | 32.4 | 49.0 | 48.1 | 3.5 (5) | 3.2 | 6.6 | 14.6 | 3.6 | 12.6 | 1.54 | 0.46 |
| | 수 | 13.7 | 18.0 | 42.9 | 5.2 | 26.9 | 8.6 | 31.9 | 48.0 | 49.1 | 7.6 (2) | 2.9 | 6.4 | 15.5 | 3.5 | 11.2 | 1.21 | 0.55 |
| | Total no. | 8 | 8 | 7 | 7 | 7 | 5 | 9 | 8 | 7 | | 7 | 7 | 7 | 8 | 7 | 5 | 7 |
| | Mean | 14.8 | 18.4 | 42.4 | 5.7 | 27.0 | 8.3 | 32.8 | 48.8 | 48.3 | | 3.2 | 6.6 | 14.7 | 3.6 | 12.2 | 1.47 | 0.47 |
| 451～500 | 우 | 15.8 | 18.3 | 43.4 | 5.6 | 27.3 | 8.7 | 33.1 | 50.8 | 49.4 | 2.9 (3) | 3.2 | 6.5 | 15.3 | 3.4 | 11.3 | 1.36 | 0.50 |
| | 수 | 15.0 | 16.3 | 44.3 | 6.0 | 24.9 | 9.5 | 32.8 | 48.9 | 47.8 | 7.2 (1) | 2.8 | 6.2 | 15.5 | 3.6 | 11.3 | 1.20 | 0.45 |
| | Total no. | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 4 | | 4 | 4 | 4 | 4 | 3 | 3 | 4 |
| | Mean | 15.6 | 17.7 | 43.6 | 5.7 | 26.7 | 9.0 | 33.0 | 50.8 | 49.0 | | 3.1 | 6.4 | 15.4 | 3.5 | 11.3 | 1.31 | 0.49 |
| 501～550 | 우 | 16.5 | 18.8 | 44.0 | 5.3 | 25.1 | 8.5 | 31.5 | 48.8 | 46.1 | 2.9 (1) | 3.9 | 6.1 | 16.5 | 3.6 | 12.0 | 1.40 | 0.64 |
| | 수 | 14.3 | 19.1 | 41.8 | — | 23.2 | — | 33.7 | 50.6 | 50.0 | 7.9 (1) | 3.3 | — | 14.3 | 3.6 | 14.5 | — | — |
| | Total no. | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | | 2 | 1 | 2 | 2 | 2 | 1 | 1 |
| | Mean | 15.4 | 18.9 | 42.9 | 5.3 | 24.2 | 8.5 | 32.6 | 49.7 | 48.1 | | 3.6 | 6.1 | 15.4 | 3.6 | 13.3 | 1.40 | 0.64 |

## PROPORTIONS

### RELATION BETWEEN $\alpha$-VALUE AND THE PROPORTION

As the proportion is the ratio of a portion to other portion, it is of course related with the relative growth. In other word, proportion and relative growth are inside and outside each other to represent the growth of portions.

Fig. 8 a, b show the relation between the relative growth and proportion. If $\alpha$-value is larger than 1.0, proportion always increases with the increase of $x$ (B-line). When $\alpha$ equals to 1.0, proportion is constant (A-line). When $\alpha$ is less than 1.0, proportion decreases with the increase of $x$ (C-, D-, F-line).

At the point when $\alpha$ which is larger than 1.0 changes the value which is less than 1.0, the critical point is clearly recognized in the proportion (E-line). However, when $\alpha$ changes its values in the range which is larger than 1.0 or less than 1.0, the critical points are not distinct.

The larger $\alpha$-value is in the range in which $\alpha$ is larger than 1.0, the more remarkable the proportion increases. On the contrary, the less $\alpha$-value is than 1.0, the remarkable the proportion decreases. Even if $\alpha$-value is constant, the rate of increase or decrease of proportion is large, when $x$ is small quantity. But as $x$ increase, the rate becomes to decrease.

### VARIATIONS OF PROPORTION ACCORDING TO BODY LENGTH IN FOETAL STAGE

Fifteen measurements expressed as percentage of the body length (body proportions) according to the body length of the fin whale foetuses are shown in Fig. 9. And meanwhile, No. 14/No. 15 and No. 25/No. 9 according to body length are also shown in this figure. Table 9 shows the mean body proportions in each body length classes.

As discussed in the above paragraph, body proportions are able to be calculated with the allometry formula and if the body proportions are calculated with the actual measurements, they should agree with those which are calculated with the allometry formula. However, the both do not always agree with each other.

For example, although proportion of measurement No. 11 should be a increasing curve by the calculation with the allometry line, the mean proportion shows a waving curve having a peak in body length of 70 cm and a valley in the body length of 140 cm. Proportion of measurement No. 12 calculated with allometry line is a similar curve as No. 11. However, the actual mean proportion is a convex curve having a valley

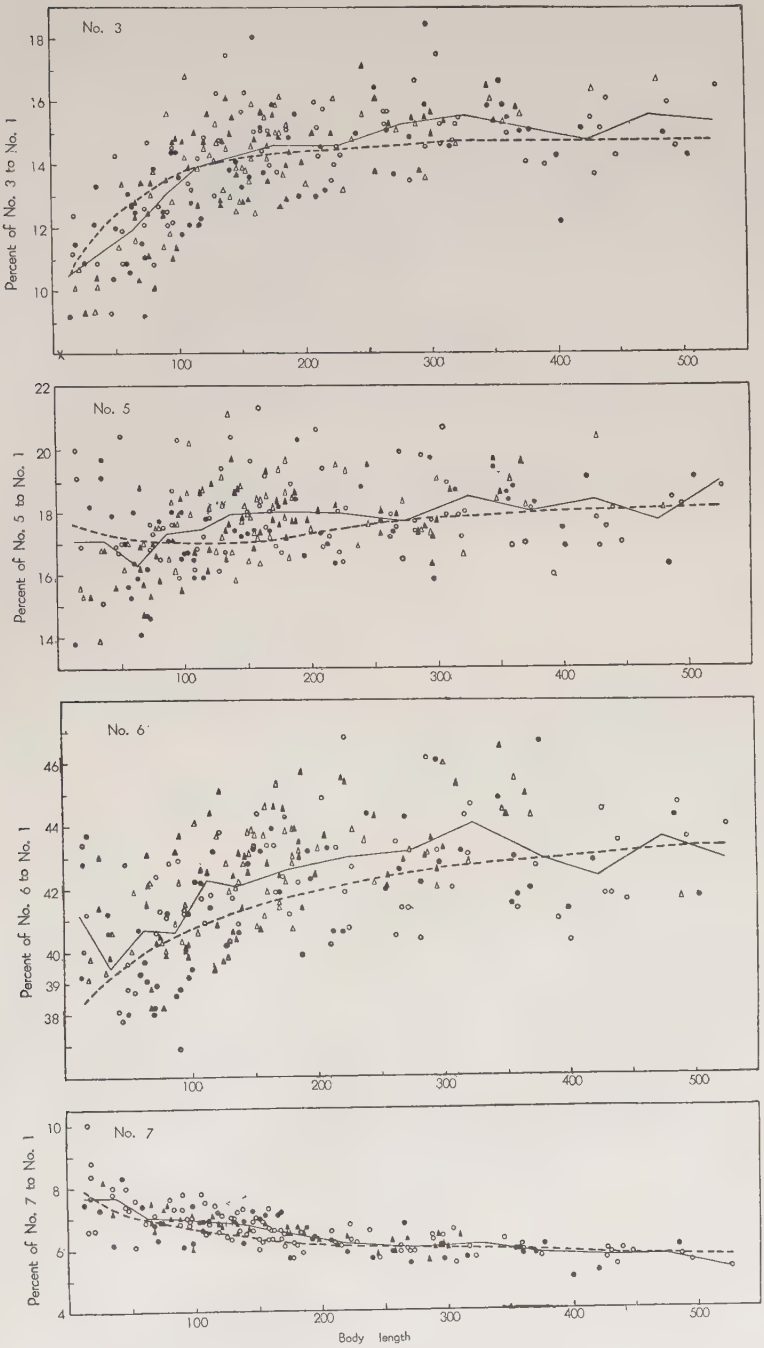



Fig. 9. Variation of the proportions of measurements in the fin whale foetuses. Open circle: Antarctic female, closed circle: Antarctic male, Open triangle: North Pacific female, closed circle: North Pacific male, Solid line: Mean proportion in each body length class, Broken line: Proportion calculated from allometry.

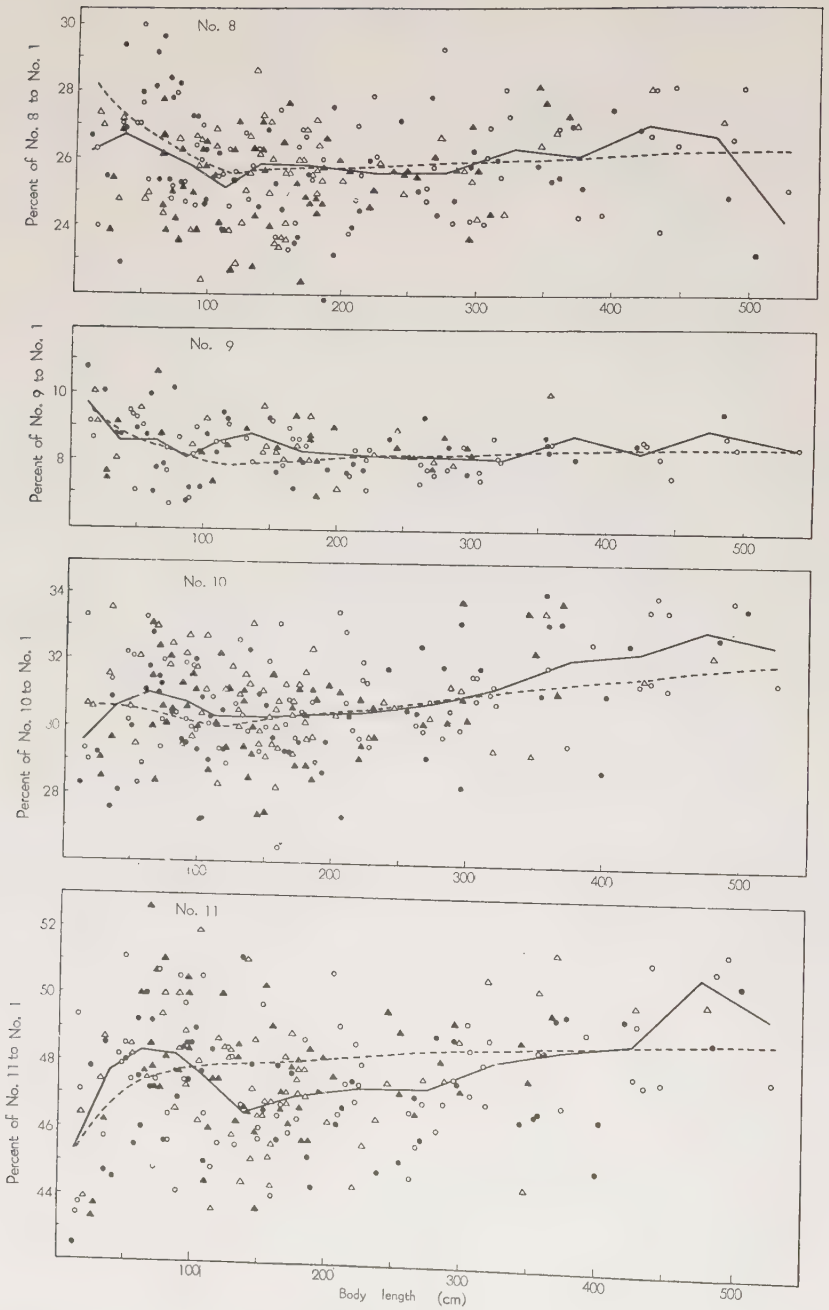

No. 8
Percent of No. 8 to No. 1
30
28
26
24
100
200
300
400
500
No. 9
Percent of No. 9 to No. 1
10
8
100
200
300
400
500
No. 10
Percent of No. 10 to No. 1
34
32
30
28
100
200
300
400
500
No. 11
Percent of No. 11 to No. 1
52
50
48
46
44
100
200
300
400
500
Body length (cm)

Fig. 9. (Cont.)

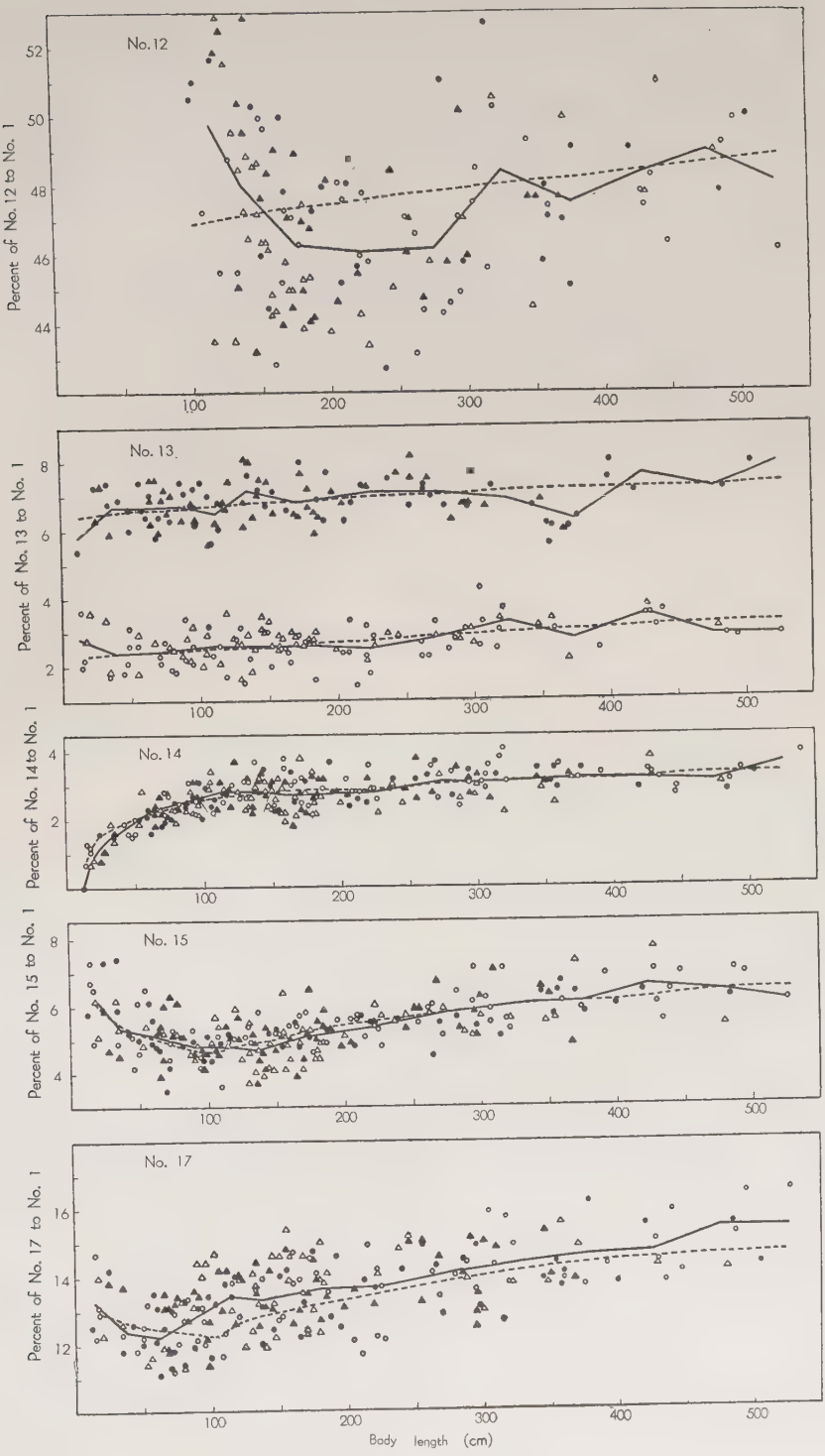

No. 12
Percent of No. 12 to No. 1
52
50
48
46
44
100
200
300
400
500
No. 13
Percent of No. 13 to No. 1
8
6
4
2
No. 14
Percent of No. 14 to No. 1
No. 15
Percent of No. 15 to No. 1
No. 17
Percent of No. 17 to No. 1
16
14
12
Body length (cm)

Fig. 9. (Cont.)

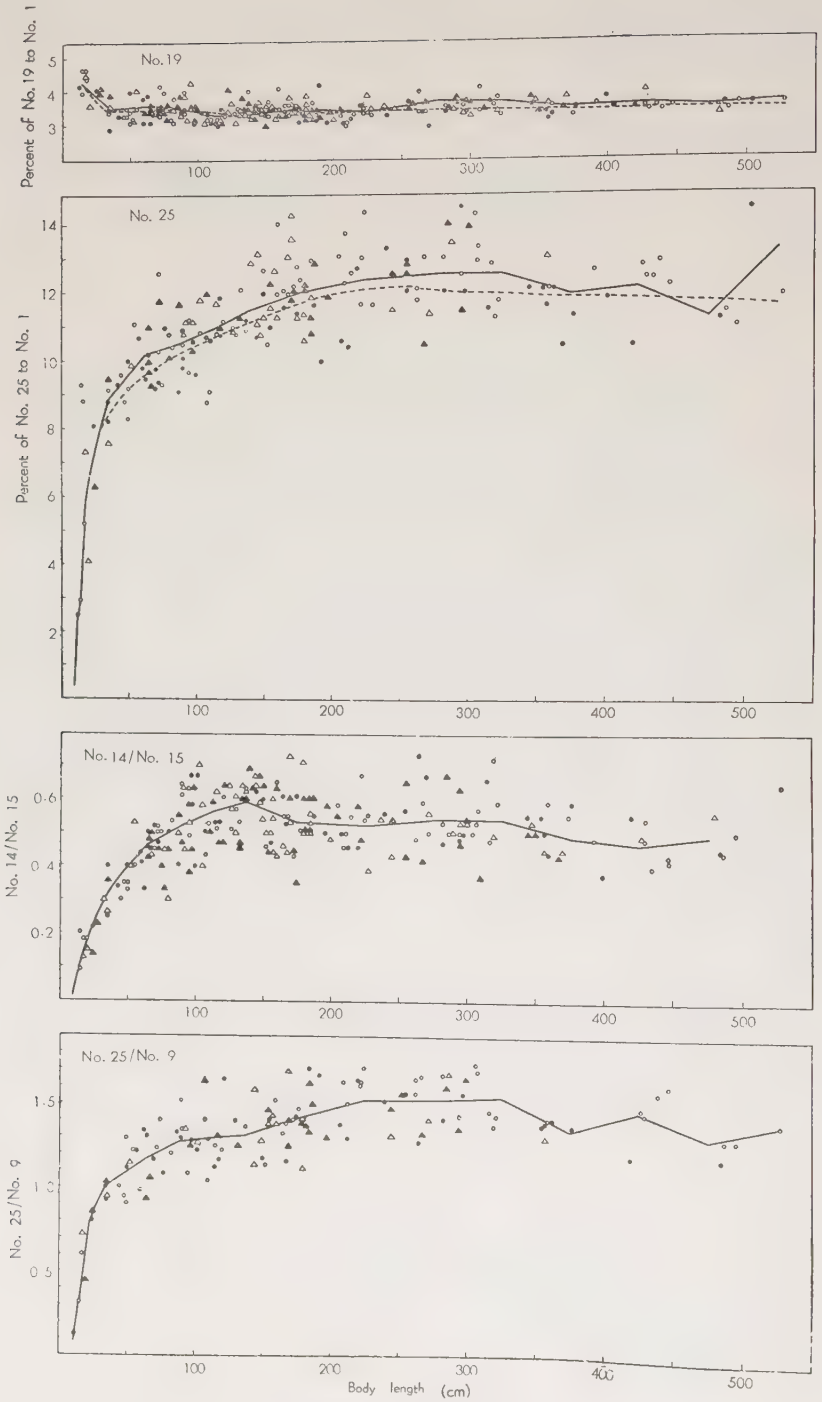

Percent of No. 19 to No. 1
No. 19
Percent of No. 25 to No. 1
No. 25
No. 14/No. 15
No. 25/No. 9
Body length (cm)

Fig. 9. (Cont.)

in the body length of 220 cm. And after the point, the rate of increase of the latter is larger than the former.

In the measurement No. 17, the both proportions fairly agree with each other, but the curve of proportion calculated with allometry has a valley in the body length of 110 cm, on the contrary, the mean proportion has a valley in the body length of 60 cm.

Zemskiy (1950) calculated the body proportions of the southern fin whale foetuses according to the body length from 49.5 cm to 569 cm.

The external parts measured by him are as follows.

1) From tip of snout to umbilicus (No. 1 minus No. 11.)
2) From tip of snout to anus (No. 1 minus No. 10).
3) Girth in thoracic region at the level of the thoracic flipper. Not measured in this paper.
4) Girth of body at the level of anus. Not measured in this paper.
5) From tip of snout to ear (No. 5 plus No. 7).

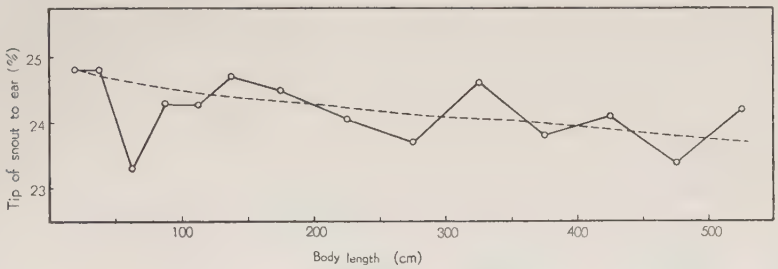



Fig. 10. Variation of the proportion of the length of head (No. 5+No. 7) in the fuetal stage of fin whales.

Then Zemskiy states that both male and female embryos, the proportions of the different parts of the body remain almost constant throughout the whole of the period of development studied, and that it is possible that the earliest stages disproportion is present, but that this has disappeared by the time when the foetus reaches to 50 cm in body length.

And he shows the figures of proportions as follows:

| *Measurement by Zemskiy* | *Mean (%)* | *Maximum (%)* | *Minimum (%)* |
|---|---|---|---|
| 1 | 52.4 | 57.1 | 47.5 |
| 2 | 68.7 | 74.6 | 68.7 |
| 5 | 24.7 | 26.7 | 23.8 |

Now, according to my result, the proportion of the above three measurements are not constant. In the measurement No. 1 by Zemskiy, the proportion in the time when body length of 50 cm is reached is 52.9%. Then the proportion decreases and becomes to 51.1% by the time when body length of 500 cm is reached. In measurement No. 2 by Zemskiy, the

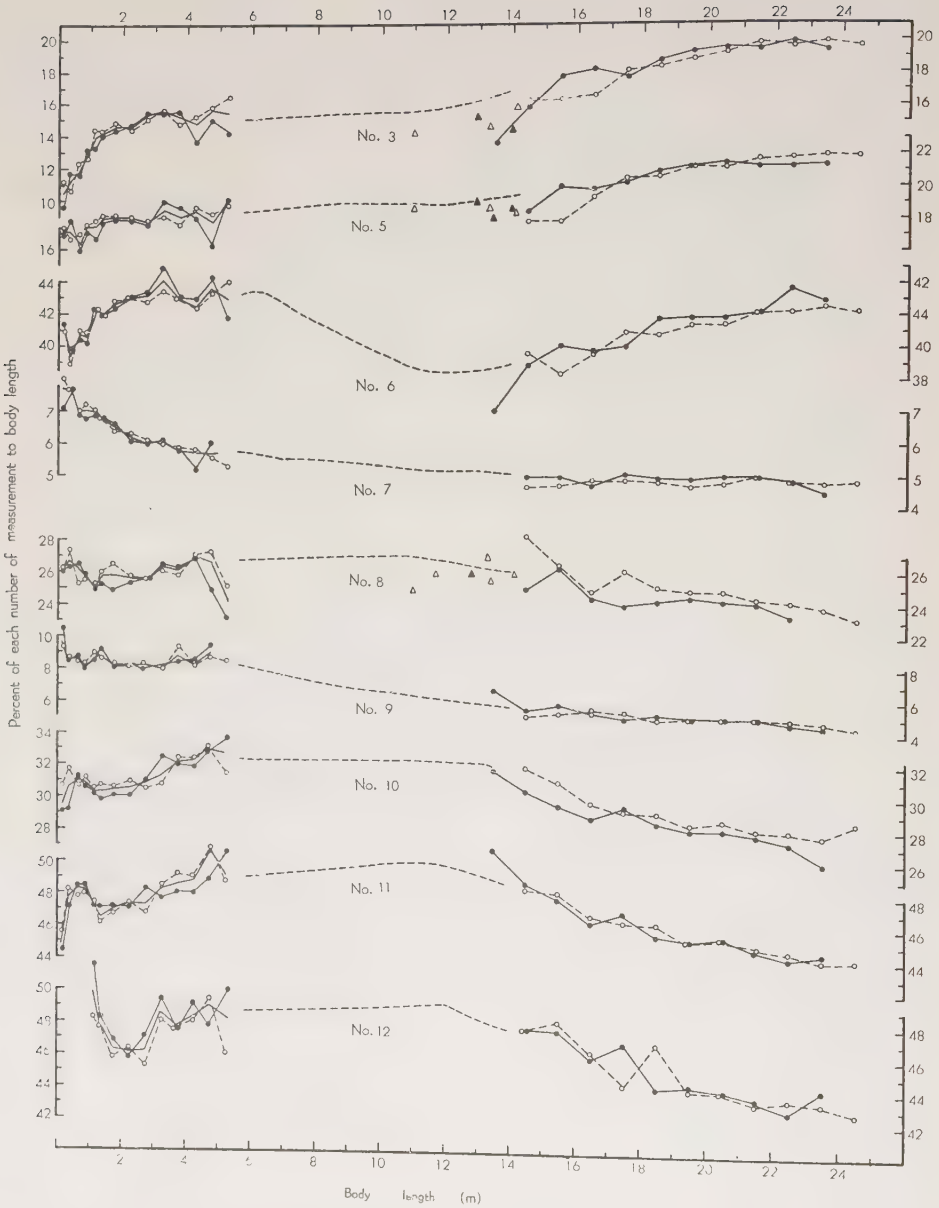



Fig. 11. Variation of body proportions throughout life of the Antarctic fin whale. Open circles and line: female. Closed circles and thin solid line: males. Open triangle: North Atlantic female. Closed triangle: North Atlantic males. Broken curve: estimated variation of body proportion calculated from allometry. Circles over 13 m: After Mackintosh & Wheeler (1929). Triangle: After True (1904).

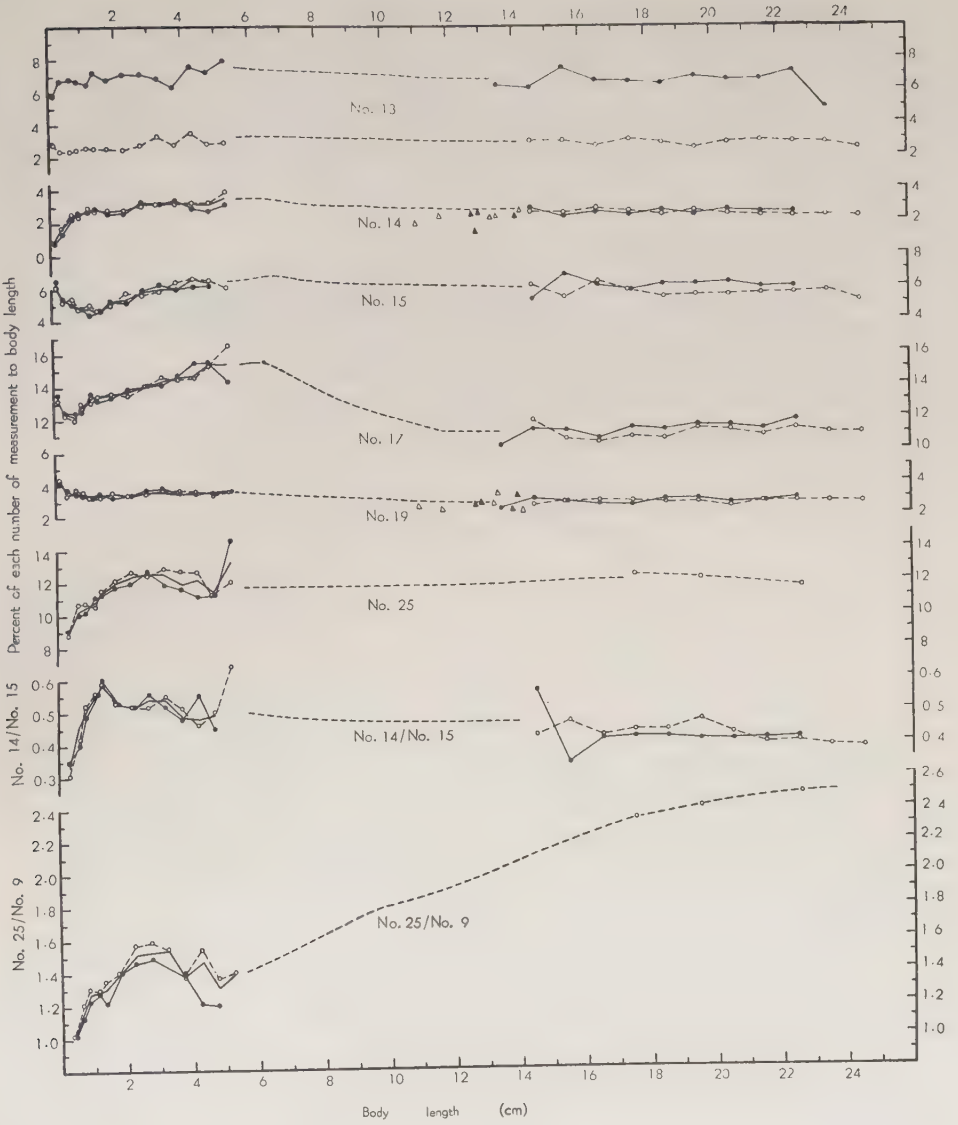



Fig. 11. (Cont.)

proportion is 69.2% in body length of 50 cm. After then it increases to be 69.8% in the body length of 110 cm. And after then it decreases to be 67.2% by the time when body length of 500 cm is reached. Measurement No. 5 by Zemskiy is considered to agree with the measurement No. 5 plus No. 7 of this paper. Fig. 10 shows the variation of proportion of No. 5 plus No. 7 according to the body lengths. From this figure the proportion of measurement No. 5 by Zemskiy is 24.5% in 50 cm long foetuses, and it decreases gradually to become 23.8% by the time body

length of 500 cm is reached.

Mackintosh & Wheeler (1929) show a table of body proportions for each measurements of fin whale foetuses in each 1.0 m body length classes. But they did not discuss on the proportion of foetuses. And they did not classify narrow body length classes chiefly in small body length, so the variation of proportions in the small body length is not compare with my results.

By the matter that it may, Mackintosh & Wheeler's figures do not show that proportions are constant in the foetal stage as shown by Zemskiy, and they agree with my result in general. Comparing the both Mackintosh & Wheeler's and my results in detail, both do not always agree each other (Nos. 5 and 9). Besides, in Nos. 11, 12 and 19, variations of proportions are reverse each other.

## VARIATIONS OF BODY PROPORTIONS THROUGHOUT THE LIFE HISTORY OF THE FIN WHALE

It will be important to study the ratio of external measurements throughout the life history of the fin whale. Now, I recorded the body proportions of the measurements in Fig. 11. The body proportions in foetal stage are given in the Table 9. Those in the adult stage over 13 m are cited after the table of Mackintosh & Wheeler (1929). As the data on the proportions of the individuals from 600 cm till 1,300 cm are very few, proportions are calculated from the figures of the relative growth.

True (1904) presented several measurements on the external parts of fin whales from the North Atlantic. I recorded the measurement of five individuals less than 1,415 cm in Fig. 11.

*No. 3.* Proportion increases remarkably until the body length of 110 cm (from 10% till 14%). After then it increases slowly until 12 m (15.8%). From 12 m till 21 m, the rate of increase of proportion again enlarges (19.5% in 21 m). After 21 m it seems to decrease a little. The proportion of the North Atlantic fin whales is lower than that is calculated by means of relative growth.

*No. 5.* In the body length of 10 cm, the proportion is 17.6%, and then decreases until 17.0% in 120 cm. After then it increases slowly until the body length of 12 m (18.8%). From 12 m the rate of increase of proportion becomes large and it becomes 21.4% in 21 m. After then it becomes almost constant.

*No. 6.* This proportion varies remarkably. It increase from 40% to 43.4% by the body length of 6.5 m. After the length it decrease reversely until 12 m (38.4%). From the length it again increase, and by the time the body length is reached 12 m long, it becomes 42.7%. As

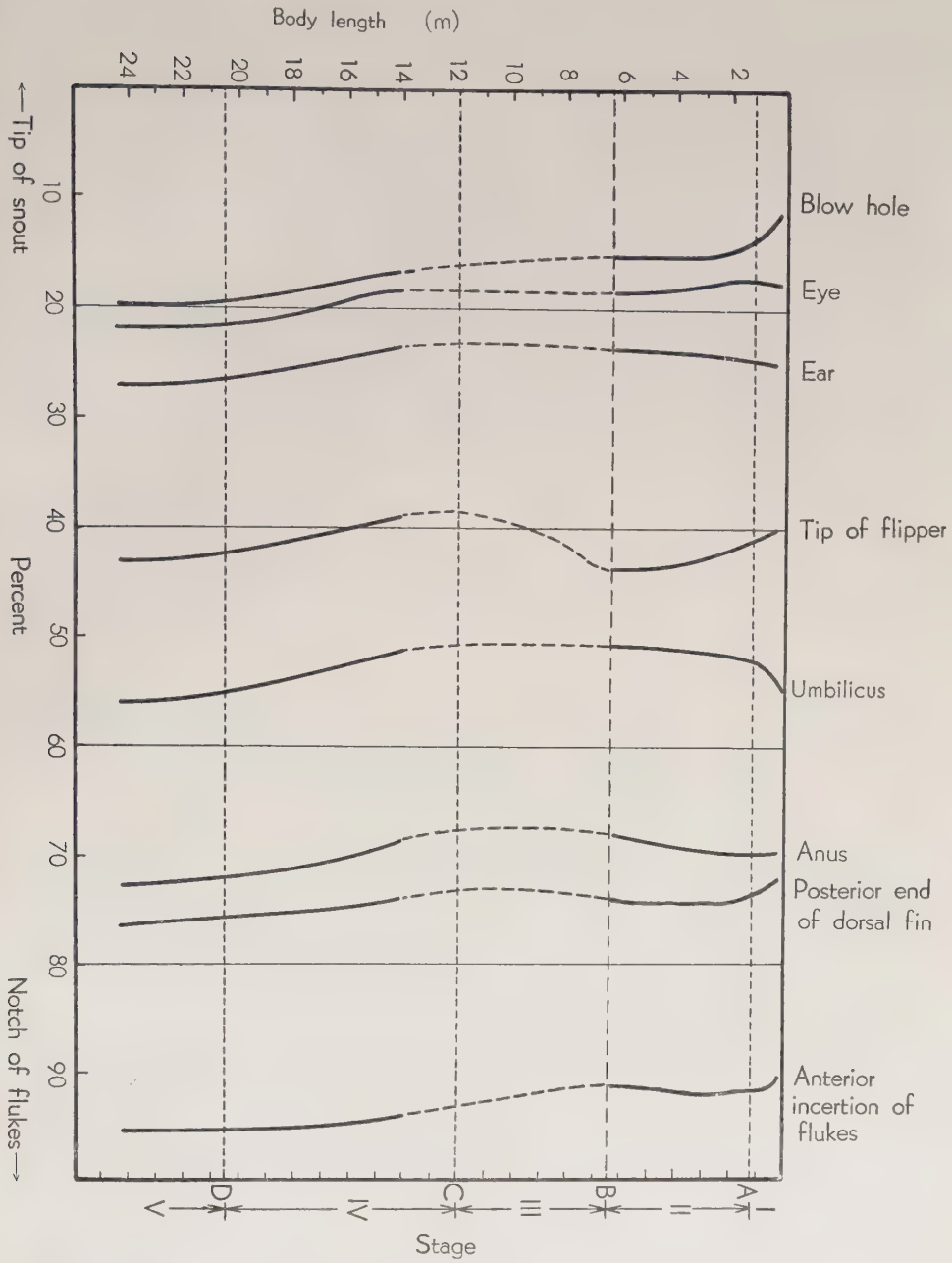



Fig. 12. Variation of the position of external parts accompanying to the growth in body length of the Antarctid fin whale.

shown in the proportion of No. 17, this phenomenon is closely related to the variation in the proportion of the length of flipper.

*No. 7.* This proportion continous to decrease throughout the life his-

tory. It is 8.1% in the body length of 10 cm, but it becomes to be 4.7% in 24 m.

*No. 8.* Decreases until 110 cm, and at that time it is 25.5%. After then it increases to be 27.0% in 11 m. After 11 m it again decreases. The proportion is 23.6% in the body length of 24 m.

*No. 9.* It is 10% at 10 cm and it decrease until 7.9% in the body length of 120 cm. In 530 cm it becomes to be 8.5%. After then it continuously decreases and it is 4.6% in 24 m.

*No. 10.* On the variation of the proportion in the foetal stage was already described in the previous paragraph. The proportion has a peak (31.0%) at the body length of 75 cm and a valley (30.3%) at 120 cm. After then it increases to become to 32.3% by the time the body length is reached 12 m. Over the length it decreases reversely and it is 26.9% at 24 m.

*No. 11.* The mean proportion at 10 cm is 44.5% and has a peak (48.3%) at 75 cm, and a valley (46.5%) in 130 cm. After 12 m, it decreases slowly and it is 44% at 24 m. Calculating the proportion with the allometry formula, there is no peak or valley and continuously increases in the foetal stage.

*No. 12.* This proportion is present from body length of 0.9 m. It has a valley in the body length of 225 cm. The proportion in this body length is 46.1%. After then it increase until 12 cm (49.2%). Then it begins to decrease, and it is 43% at 24 m.

*No. 13.* Although the proportions are different between males and females, they are almost constant throughout the life. Merely in foetal stage, they increase a little, and after then they decrease also a little. In 50 cm, the proportions are 6.5% in males and 2.4% in females. In 650 cm, they are 7.5% and 3.5% in males and females respectively. They become to be 6.6% and 2.8% respectively in adult stage.

*No. 14.* Dorsal fin does not develop until the body length grows 10 cm long. The proportion increases from that time till birth. At birth (650 cm) it will be 3.6%. After then it decreases slowly. It is 2.2% at 24 m.

*No. 15.* The proportion decreases from 20 cm till 110 cm. And it is 4.6% at 110 cm. Next, it increase to be 6.8% in 650 cm. After birth it again decrease, In 24 m, it is 5.7%.

*No. 17.* The mean percent of the measurement has a valley (12.2%) at the body length of 60 cm. Calculating it from the allometry, it should have a valley in 107 cm. After then it increases until the time at birth. The proportion is 15.5% in 650 cm. Then it decreases remarkably until the time at weaning. And at weaning, it will be 11.2%. After that time it becomes almost constant.

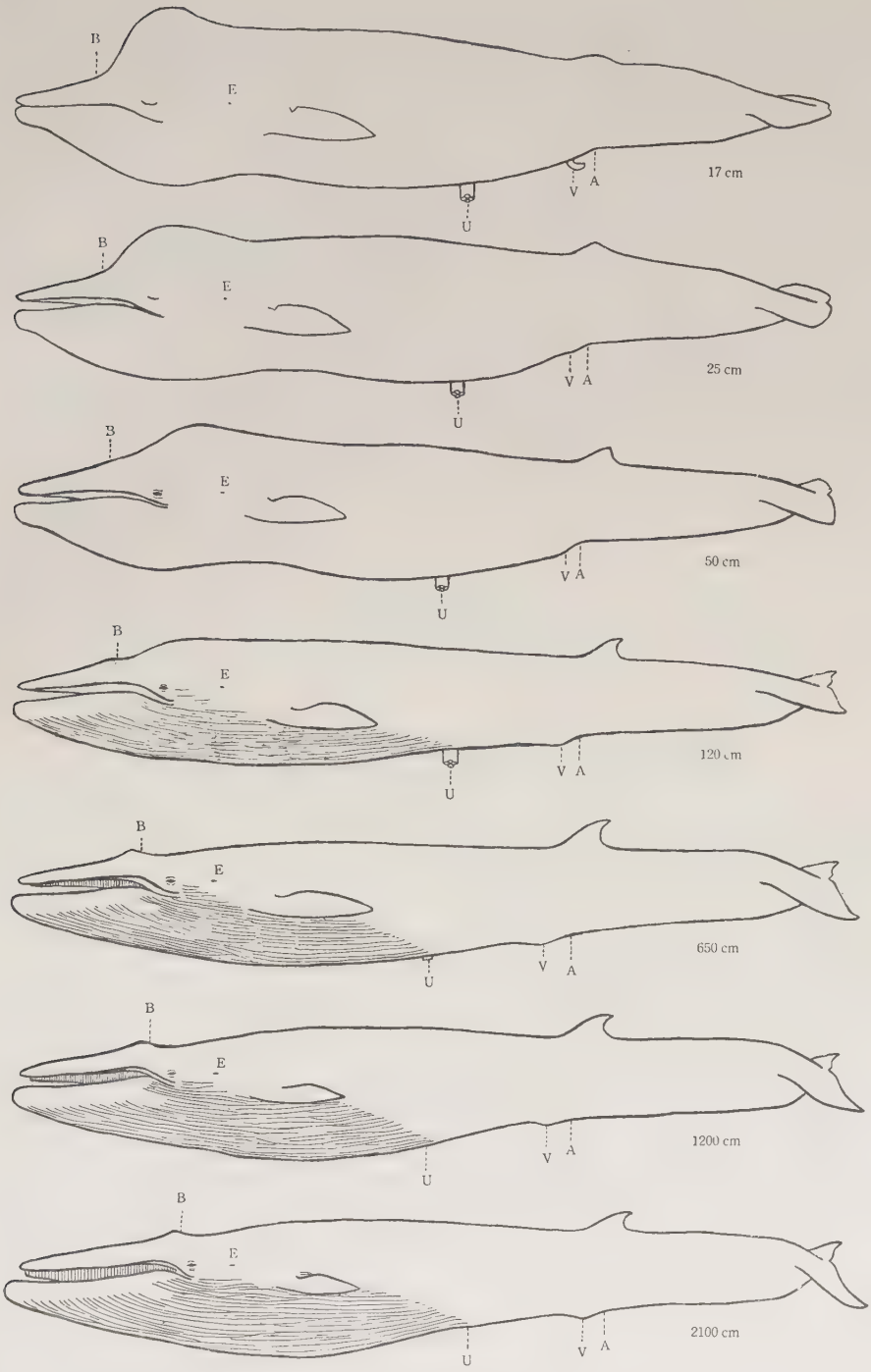



Fig. 13. Variation of the external form in the female fin whales.
A: Anus, B: Blow hole, E: Ear, U: Umbilicus, V: Vagina opening

*No. 19.* The variation of the proportion of this measurement is not so remarkable. It decreases until 30 cm. At that length it is 3.5%. After then, it increases until the time at birth, then turns to decrease until the time at weaning. After weaning it is almost constant. In 24 m, the proportion is 2.8%.

*No. 25.* The mean proportion increases until 325 cm. At that length it is 12.6%. Calculating the proportion from the allometry it becomes maximum (12.3%) at 250 cm. After then it decreases until the time at birth. It is estimated to be 11.7% at that time. Because there are only three measurements in the adult stage, the variation of the proportion is not confirmed, but it seems to increase a little.

*No. 14: No. 15.* The ratio of the height of dorsal fin to the length of base of the dorsal fin increases rapidly with the body length until the time the body length reaches 140 cm. The maximum ratio is 0.59. After then it decreases gradually, and it becomes to be 0.40 at 24 m.

*No. 25: No. 9.* The ratio of the length of tail flukes (notch to tip) to the width at insertion of flukes varies remarkably according to the increase of body length. Although it is only 1.0 at 40 cm, it increase to be 1.55 at 300 cm. After the length, it decreases until the time at birth. After then it increases again and becomes to be 2.5 at 24 m.

## VARIATION OF THE PROPORTIONS OF THE SEVERAL PARTS ALONG THE BODY AXIS

From the anterior end of the body, I arranged the following portions along the body axis:

Blow hole (No. 3), eye (No. 5), ear (No. 5+No. 7), tip of flipper (No. 6), umbilicus (No. 11), anus (No. 10), posterior emargination of dorsal fin (No. 8), and anterior emargination of flukes (No. 9).

Fig. 12 shows the variation of the proportions of the above portions throughout the growth of fin whales.

In the foetal stage, the proportion of both anterior and posterior portion increase with the increase of body length. And the ratio from ear to umbilicus decreases relatively. In this stage, the tip of flipper spreads remarkably posteriorly. In the sucking stage (650–1,200 cm), the anterior emargination of flukes shrinks posteriorly and the tip of flipper removes anteriorly. The other portions do not vary so remarkably.

After weaning, all portions remove posteriorly. As stated by Mackintosh & Wheeler (1929), anterior parts relatively increase as the body length increase, and the posterior parts show correspondingly decrease. The proportions of middle parts (ear—anus) do not vary, so remarkably, but they remove posteriorly accompanying the increase of head and

decrease of tail.

Fig. 13 shows the side-view of fin whales in the body lengths of 17 cm, 25 cm, 50 cm, 120 cm, 650 cm, 1200 cm and 2,100 cm.

## COMPARISON OF THE RELATIVE GROWTHS AMONG THE SIX SPECIES BELONGED TO *BALAENOPTERIDAE*

### COMPARISON OF THE BODY PROPORTIONS AMONG THE FIVE SPECIES BELONGED TO *BALAENOPTERAE*

It is regarded that there is five species: blue whale (*Balaenoptera musculus*), fin whale (*B. physalus*), sei whale (*B. borealis*), Bryde's whale (*B. edeni*), minke whale (*B. acuto-rostrata*) belonged to *Balaenoptera*.

The external characters and the body lengths at sexual maturity are different among the five species. And in the same species, they are also different among the races.

In the above chapter, I studied the variation of the proportions over the body length of 10 cm. And I found that the proportions vary as the increase of body length. Then I thought that the whales may have the form adapted best to the body length at that time. For example, the proportion of the height of dorsal fin (No. 14) decreases as the increase of body length after the time of birth. This will mean that the smaller whales need to have heigher dorsal fin, and accompanying the increase of body length, they become to need the lower dorsal fin.

Standing on this idea, I examine the relation between the differentiation of the proportions among five species which are different in body length at sexual maturity and the variation of the body proportions accompanying the body length of fin whales.

The data which are used in this chapter are all the mean proportions of the different external measurements in the adult stage. And the authors, localities, ranges of body lengths and the body lengths at sexual maturity of the species are shown in Table 10.

Fig. 14 shows the mean proportions and the range of the proportions in the five species. In this figure whale species are arranged according to the body length at sexual maturity in principle. However, *B. borealis* and *B. edeni* are exchanged. Because *B. borealis* is near *B. acuto-rostrata* morphologically, and *B. edeni* is near *B. physalus*.

Used data include immature whales as well as mature whales. As shown in the variation of the proportions of fin whales, proportions vary with the body length. Therefore, it will be given the better result if the comparison is limited to the matured whale. But because of the relative scanty of the dada, I used all the data. The materials are considered to be given all from the individuals after weaning.

TABLE 10. DATA ON MEASUREMENT FOR THE SIX SPECIES OF *BALAENOPTERIDAE* WHICH ARE DISCUSSED IN THIS REPORT

| Species | Authors | Locality | | Measured individuals | Range of body length measured (m) | Body length at sexual maturity (m) |
|---|---|---|---|---|---|---|
| Genus *Balaenoptera* | | | | | | |
| *B. musculus* | Mackintosh & Wheeler (1929) | South Georgia | Females | 268 | 16～29 | 23.5[f] |
| | | | Males | 256 | 17～27 | 22.6[f] |
| *B. physalus* | Mackintosh & Wheeler (1929) | South Georgia | Females | 257 | 14～25 | 19.9[b] |
| | | | Males | 360 | 13～24 | 19.2[b] |
| *B. edeni* | Omura, Nishimoto & Fujino (1952)[a] | Bonin Islands[g] | Females | 113 | 12.2～14.2 | 12.5[c] |
| | | | Males | 85 | 12.2～14.3 | 12.3[c] |
| *B. borealis* | Matthews (1938b) | South Georgia | Females | 137 | 12.1～17.1 | 14.5[d] |
| | | | Males | 53 | 11.3～16.2 | 13.5[d] |
| *B. acuto-rostrata* | Omura & Sakiura (1956) and Ohsumi (1960) | Coast of Japan | Females | 20 | 4.61～8.57 | 7.3[e] |
| | | | Males | 22 | 4.86～7.98 | 6.7～7.0[e] |
| Genus *Megaptera* | | | | | | |
| *M. novaeangliae* | Matthews (1960) | South Georgia | Females | 26 | 10～15 | 11.0[f] |
| | | | Males | 18 | 11～15 | 11.9[g] |

*a*) Identified as *B. edeni* by Omura (1959) *b*) Mackintosh (1942) *c*) Nishiwaki, Hibiya & Ohsumi (1954) *d*) Matthews (1938b)
*e*) Omura & Sakiura (1956) *f*) Chittleborough (1955b) *g*) Chittleborough (1955a)

*No. 3.* Proportion is smaller in the smaller species. And it agrees well with the variation of the proportion in the fin whale after weaning.

*No. 5.* It shows the same tendency as No. 3.

*No. 6.* The smaller the species is, the smaller the proportion is, but

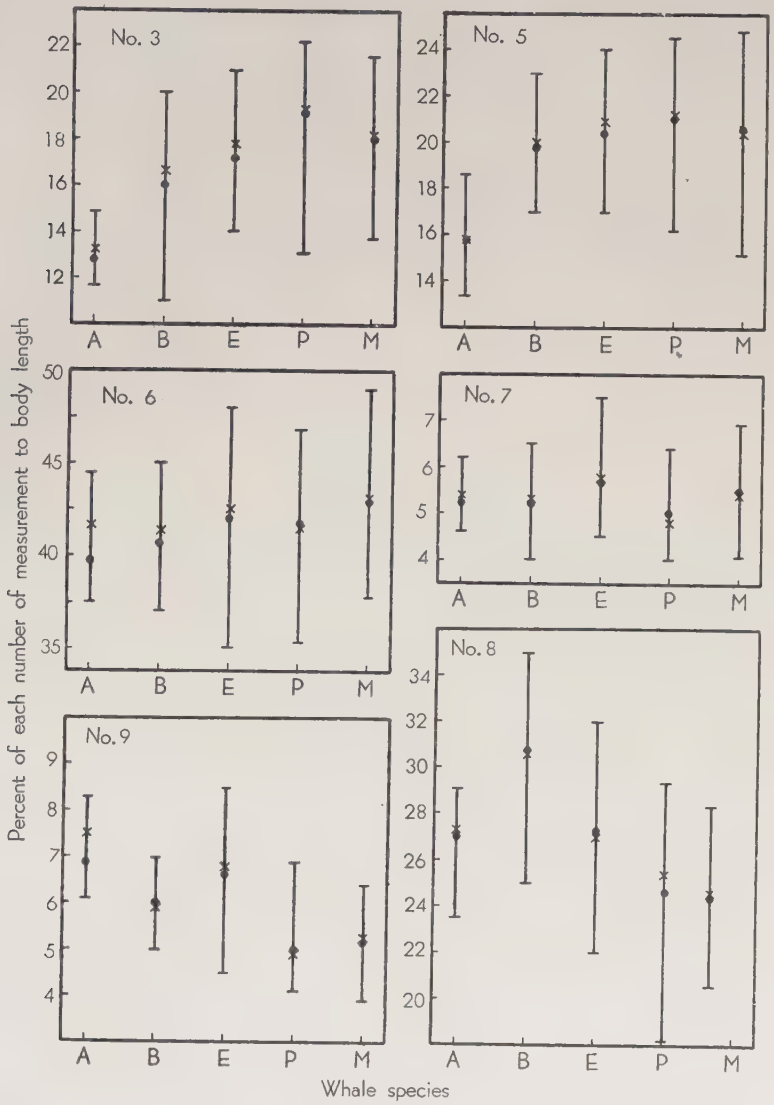



Fig. 14. Comparison of mean body proportions among the five species belonged to *Balaenoptera*.

——|: range of proportion, Cross: mean proportion of female closed circle: mean proportion of male, A: *Balaenoptera acuto-rostrata* from coast of Japan, B: *B. borealis* from the Antarctic, E: *B. edeni* from Bonin Istands, P: *B. physalus* from the Antarctic, M: *B. musculus* from the Antarctic.

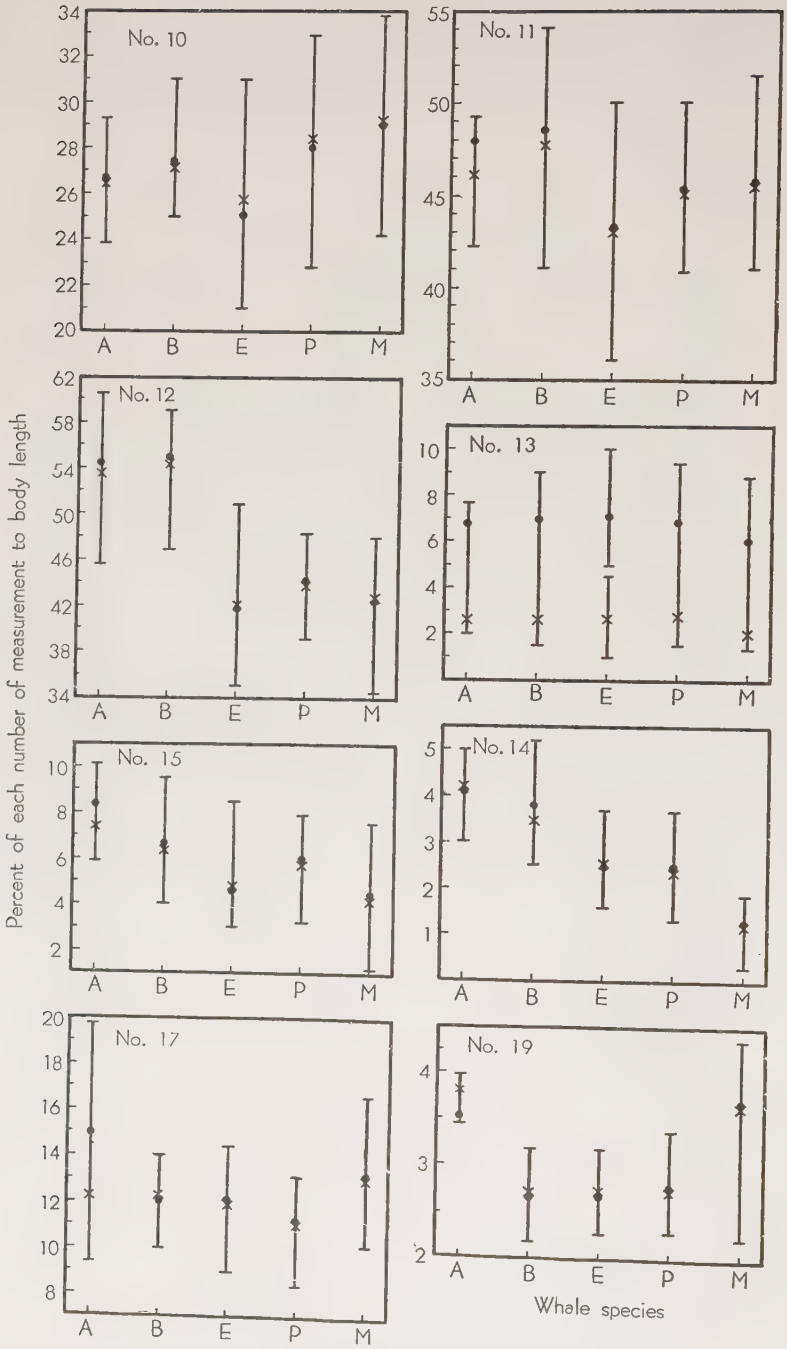

No. 10
No. 11
No. 12
No. 13
No. 15
No. 14
No. 17
No. 19
Percent of each number of measurement to body length
A B E P M
Whale species

Fig. 14. (Cont.)

it is not so remarkable as the variation of proportion in the fin whale.

*No. 7.* It is almost constant among all species. The tendency resembles to that of the fin whale.

*No. 8.* Except that the proportion of *B. acuto-rostrata* is smaller than that of *B. borealis*. The tendency resembles the variation of the proportion in the fin whale.

*No. 9.* If the proportions of *B. borealis* and *B. edeni* are not exchanged, the difference of proportion resembles to the variation in the fin whale.

*No. 10.* It does not agree with the variation in the fin whale. Proportion of *B. edeni* is the smallest.

*No. 11.* Except *B. edeni*, smaller species seem to have larger proportions, but the tendency is not clear. Proportion value of *B. edeni* is the smallest.

*No. 12.* The tendency that the proportions of smaller species are larger than that of larger species, resembles to the variation of fin whales. But this measurement is classified clearly into two groups. *B. acuto-rostrata* and *B. borealis* are belonged to one group and *B. edeni*, *B. physalus*, *B. musculus* are belonged to another group.

*No. 13.* Proportions are different between males and females. And they are almost constant among the five species. This tendency resembles to the variation of the proportion as the increase of body length of the fin whale.

*No. 14.* The smaller the species is, the larger the proportion is. And this tendency agrees with the variation in the fin whale. But the tendency of the former is more remarkable than the latter.

*No. 15.* Excluding *B. edeni*, the tendency is the same as No. 14. Proportion value of *B. edeni* is relatively small.

*No. 17.* The proportion is constant in all body length after weaning. But there are differentiations in the proportions of five species.

*No. 19.* The proportion is almost constant in the fin whale after weaning. But this measurement is classified into two groups of species. The proportion of one group in which *B. acuto-rostrata* and *B. musculus* are included is larger than that of another group into which *B. borealis*, *B. edeni* and *B. physalus* are belonged.

By the above examination, it is found that the differences of body proportions among the five species belonged into *Balaenoptera* agree fairly with the variations of same proportions of the fin whale accompanying the growth in many parts.

But there are some parts which have different tendency from the

variations of the proportion in the fin whale.

## COMPARISON OF THE RELATIVE GROWTH AMONG SIX SPECIES BELONGED TO *BALAENOPTERIDAE*

Range and mean value of the proportions were studied in the above paragraph. At that time the factor of body lengths is only represented by arranging the species in order of the body length at sexual maturity. And then *B. borealis* and *B. edeni* are exchanged each other.

Proportions should vary as the increase of body lengths, but this does not represented in above figure. Now, the relative growth will be more ideal for the purpose of comparison of the proportion in the same length.

Fig. 15 shows the relative growths between body length and the 14 measurements in the adult stage of six species belonged to *BALAENOPTERIDAE*.

*No. 3.* The relative growths of five species belong to *Balaenoptera* put all in order on almost one straight line. On the contrary, the relative growth of *Megaptera* is off the straight line of *Balaenoptera*.

*No. 5.* The same as No. 3.

*No. 6.* Five relative growths of the species belonged to *Balaenoptera* are all in a straight band and are different clearly from that of *Megaptera*. However, the allometry formulas of the five species are somewhat different each other.

*No. 7.* Although *Balaenoptera* species are different each other in allometry, they are included one straight band. The relative growth of *Megaptera* is little off the band.

*No. 8.* The relative growths of this measurement are different in each species. Those of *B. acuto-rostrata*, *B. edeni*, *B. physalus* and *B. musculus* are incruded almost in one straight band. But the relative growth of *B. borealis* is off the band, and agrees with that of *Megaptera*.

*No. 9.* *B. musculus*, *B. physalus* and *B. borealis* are included in one band, but only *B. edeni* is excluded off the band, and its allometry formula is very different from other species. *B. acuto-rostrata* is included almost on the above band, but the a-value of the allometry formula is larger than other species. *Megaptera* shows another allometry.

*No. 10.* Except the relative growth of *M. novaeangliae* all relative growths are included in one straight band, but the allometry formulas are different each other. The smaller species have larger $\alpha$-values.

*No. 11.* The six relative growths are divided into two straight band groups. That is to say, *B. musculus*, *B. physalus* and *B. borealis* are belonged to one group, and *B. edeni*, *B. acuto-rostrata* and *M. novaeangliae* are belonged to another group.

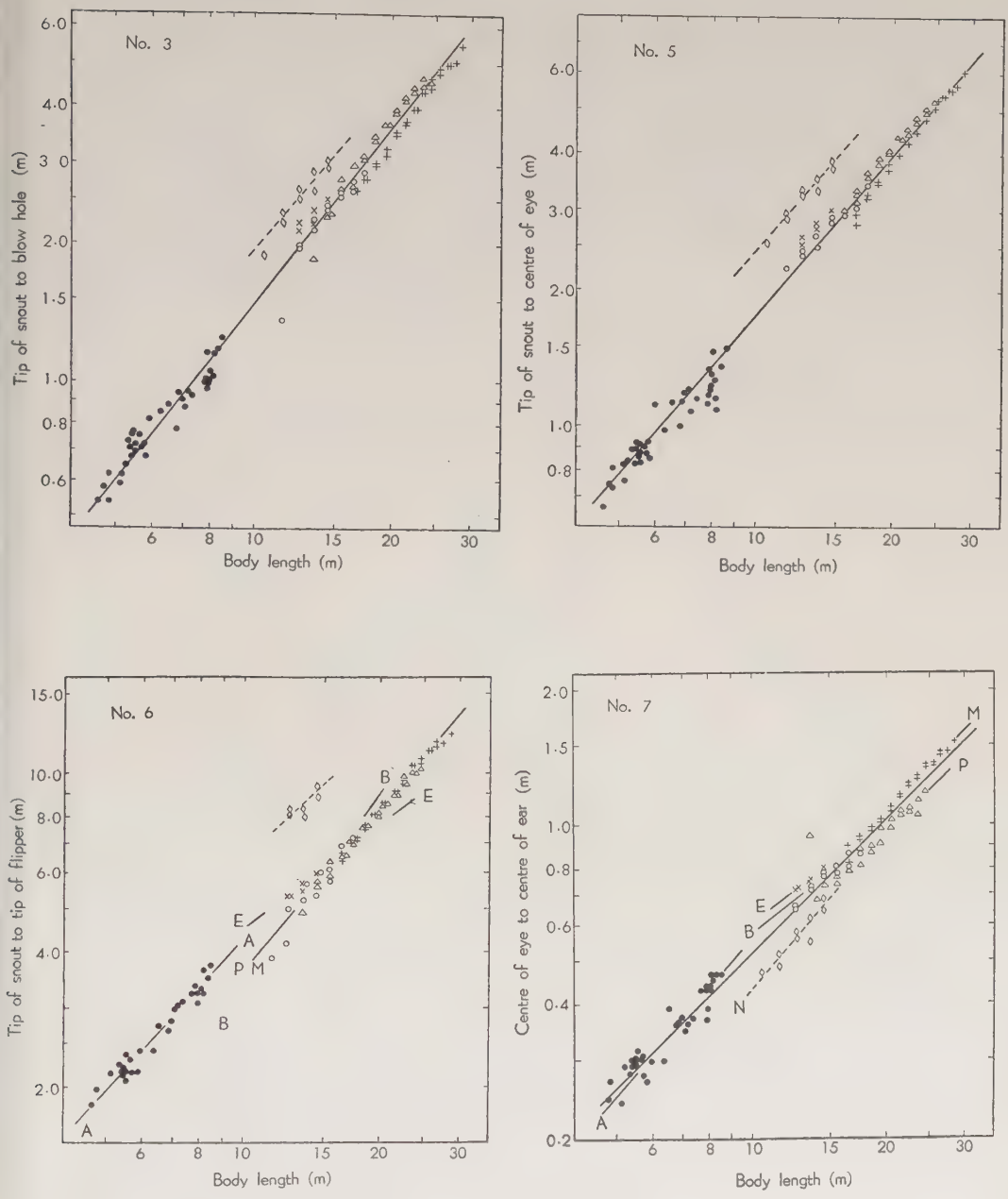



Fig. 15. Relative growths of the external measurements in the six species belonged to *Balaenopteridae*.

Closed circle: *Balaenoptera acuto-rostrata*, Open circle: *B. porealis*, Triangle: *B. physalus*, Cross: *B. musculus*, Inclined cross: *B. edeni*, Rhomb: *Megaptera novaeangliae*.

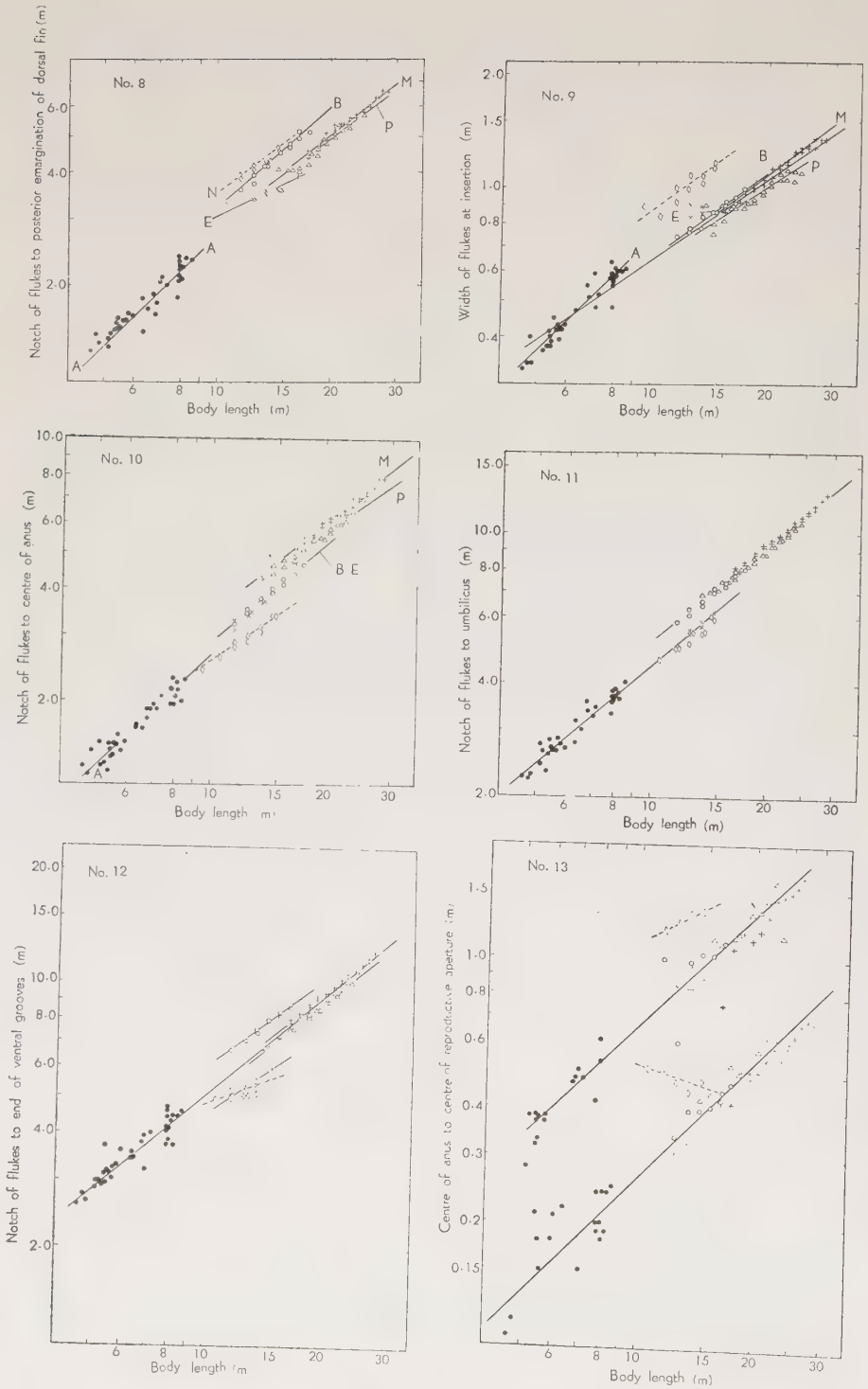

No. 8
Notch of flukes to posterior emargination of dorsal fin (m)
Body length (m)
No. 9
Width of flukes at insertion (m)
Body length (m)
No. 10
Notch of flukes to centre of anus (m)
Body length (m)
No. 11
Notch of flukes to umbilicus (m)
Body length (m)
No. 12
Notch of flukes to end of ventral grooves (m)
Body length (m)
No. 13
Centre of anus to centre of reproductive aperture (m)
Body length (m)

Fig. 15. (Cont.)

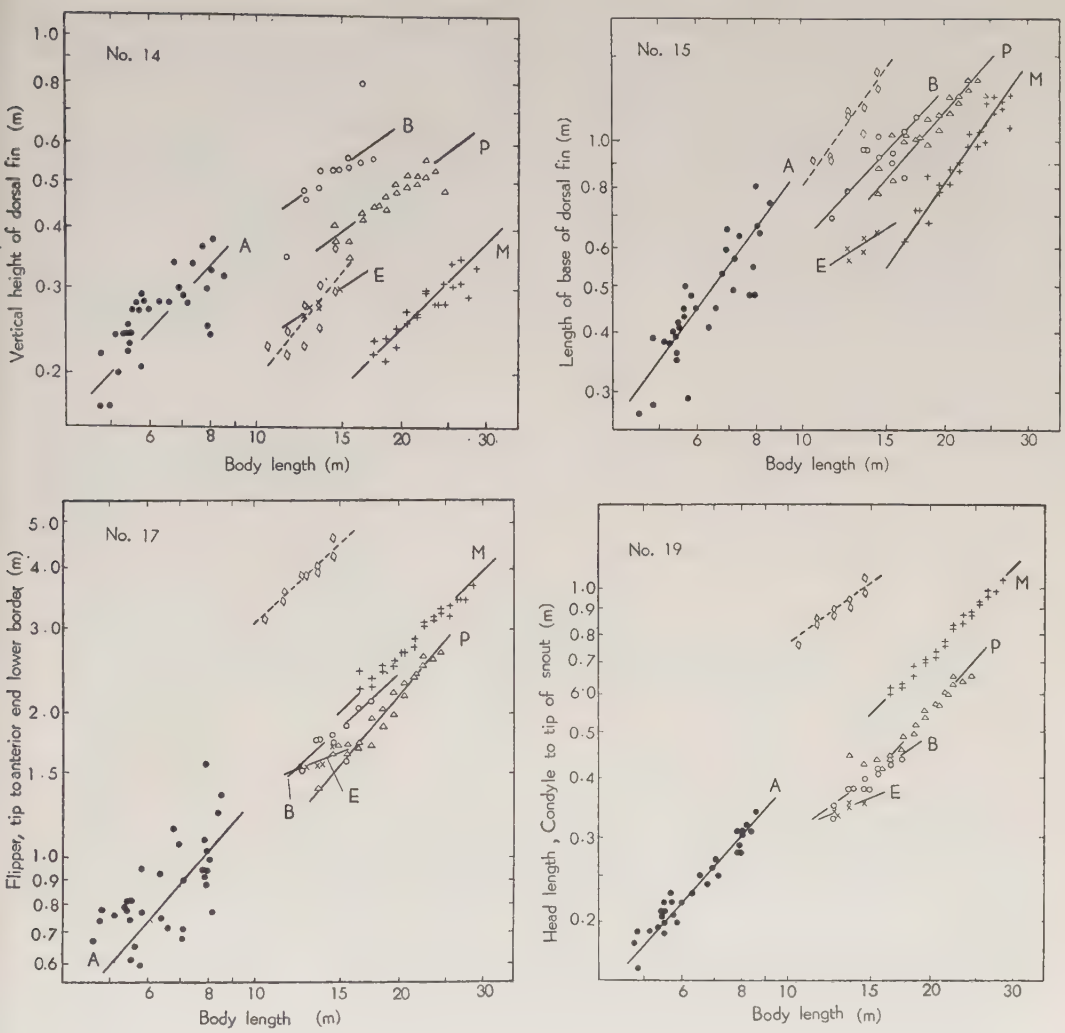



Fig. 15. (Cont.)

*No. 12.* *B. musculus*, *B. physalus* and *B. acuto-rostrata* is included in one straight band. *M. novaeangliae* and *B. edeni* compose almost one band, although they are different in the allometry formula.

*B. borealis* do not belong into any bands. Comparing the length of ventral grooves in the same body length, *B. edeni* will have the shortest grooves, and *M. novaeangliae* and *B. edeni* have the longest grooves in the six species.

*No. 13.* Although the relative growth of females is different from that of males in all species, those of both sexes in five *Balaenoptera* species are included into a straight band each other. On the contrary *M. novaeangliae* does not belong into any band. Especially, the $\alpha$-value

of the allometry in females is less than 0 (Matthews, 1937). This means that the distance between anus and vagina becomes to shorten absolutely with the increase of body length.

*No. 14.* The relative growths are very different among the six species. But although *M. novaeangliae* and *B. edeni* is different in allometry formula, they are included into the almost one band.

Comparing the height of dorsal fin in the body length of 10 m, *B. borealis* is the heighest, and the height of dorsal fin becomes lower in order of *B. acuto-rostrata*, *B. physalus*, *B. edeni*, *M. novaeangliae* and *B. musculus*.

The smaller the whale species is, the larger $\alpha$-value of allometry formula seems to become.

*No. 15.* The relative growths are very different each other among the six species. Smaller species may have larger height and base of dorsal fin in the same body length. But only *B. edeni* has small base of dorsal fin and have small $\alpha$-value in the allometry formula in spite of small species.

*No. 17.* Five species are included into a relatively wide straight band. *B. musculus* has longer flipper than *B. physalus* in the same body length. *M. novaeangliae* is very different from the band of *Balaenoptera*, and has longer flipper.

*No. 19.* The relative growths of five species in *Balaenoptera* are divided into two groups. *B. musculus* and *B. acuto-rostrata* are included in one group, and *B. physalus*, *B. borealis* and *B. edeni* compose another group. However, although they are different in their allometry formulas, the former group has wider width than the latter in the same body length. The relative growth of *M. novaeangliae* is distant from the *Balaenoptera* groups, and *M. novaeangliae* has very wide flipper.

Summarizing the examination on the relative growths of *BALAENOPTERIDAE*, conclusion is as follows:

Excepted Nos. 8, 11, 12, 14 and 15, *Megaptera* shows different relative growth from those *Balaenoptera*. Therefore, the two genera are clearly separated by means of relative growth.

Next, in five species belong to *Balaenoptera*, the relative growths are classified as follows:

1. Measurements of which relative growths of all species are included in a relatively narrow straight band.

   Nos. 3, 5, 7 and 13.

2. Measurements of which relative growth of all species are included in a relatively wide straight band.

   Nos. 6, 9, 10 and 17.

3. Measurements of which relative growths of each species arrange scatteringly.

Nos. 8, 11, 12, 14, 15 and 19.

The first group is head portions and the distance between reproductive apparature and the anus. And it may be regarded that these measurements are strongly connected with genealogy.

The third group is concerned with the external portions of shape of dorsal fin, umblicus, length of ventral grooves and width of flipper. It may be considered that these measurements are related with the beheavior of each species. The second group is concerned with the length of flipper, and shape of flukes. The group shows a relatively wide band. And the second group is the middle between the first and the third group. This may mean that the measurements belonged to the second group is connected with the genealogy and mean while with the beheavior.

It is interesting that the relative growth of the portions concerning to the length of skull agree with each other, and those which are concerned with movement are scattering each other.

And it may be noticeable that the portions of *Megaptera* which are not so different from the allometry of *Balaenoptera* agree with the third group of *Balaenoptera* except No. 19.

## CONCLUSION

It may be needful for us to study the growth of whales not only as the function of time, but also as the function of the condition of growing system itself.

So I studied the variation of the external form of fin whales in the growing system from the body length of 10 cm by means of relative growth.

The result is as follows:

1. Sixteen external portions are newly measured for 243 fin whale foetuses from the Antarctic and the northern part of the North Pacific (Appendix I).

2. Drawing the relative growths between body length and other 15 measurements, between No. 14 and No. 15, between No. 17 and No. 19 and between No. 9 and No. 25 in the growing system from the body length of 10 cm until 2,500 cm for the Antarctic fin whales, I get one monophasic allometry (No. 1/No. 7), three diphasic allometry (No. 1/No. 11, No. 1/No. 12, No. 17/No. 19) four triphasic allometry (No. 1/No. 10, No. 1/No. 14, No. 1/No. 15, No. 14/No. 15), eight four-phasic allometry (No. 1/No. 3, No. 1/No. 5, No. 1/No. 6, No. 1/No. 8, No. 1/No. 9, No. 1/No,

17, No. 1/No. 25, No. 9/No. 25) and one five-phasic allometry (No. 1/No. 19).

The means that the external portions of fin whale do not grow in constant ratio throughout the life, and the growth ratios changes several times in general.

3. Except the measurement No. 13 (distance between anus and reproductive apparature), these is no sexual difference between males and females.

4. The differences of relative growths are not recognized between the Antarctic and the North Pacific fin whales at least in the foetal stage.

5. Critical points in the relative growths of the external characters are classified into six body length groups. That is to say, all critical points stand on the body lengths of 30 cm, 100–120 cm, 300 cm, 550–650 cm, 1100–1200 cm and 200–2100 cm. And the relative growths of fin whales over 10 cm long are classified into the five stages. The end of Ia-stage (30 cm) is the first stage of the development of body colour.

In 115 cm which is the body length at the end of I-stage, the ventral grooves develop as similar as those of adult. The end of IIa-stage (300 cm) is equal to the stage of absorption of rudimental teeth and completion of development of body colour.

From 300 cm till 650 cm is regarded as the IIb-stage in the relative growth of fin whales, and the end of this stage is equal to the time at birth. The sucking period is III-stage of the relative growth. There is a critical point at the body length of the time at weaning (1200 cm). The body lengths between 1200 cm and 2100 cm is regarded as IV-stage. The end of IV-stage (2100 cm) is equal to the time of maturity. Therefore, the variation of the allometry is related with the morphological and ecological variation in the life. And the critical points exist in the growing stages when the fin whale varies largely in its development or beheavior.

6. The range of $\alpha$-values in the allometry formulas is between 0.31 and 1.85. And most of $\alpha$-values included in the range between 0.81 and 1.20. $\alpha$-values are not constant throughout life, and the changes are classified into six types (116 p.).

7. In the foetal stage, the proportion of the anterior and posterior portion increase with the growth in body length tip of flipper spreads remarkably posteriorly. In the sucking stage, the anterior emagination of flukes shrinks posteriorly and the tip of flipper removes anteriorly. The other portions do not vary so remarkably. After weaning, all portions remove posteriorly, anterior parts relatively increase and posterior parts shows correspondingly decrease.

8. Difference of body proportions among the five species in *Balaenoptera* agree fairly with the variation of the proportions accompanying the growth of body length in many external parts. And this may mean that whales have the form adapted best to the body length at that time.

9. Except Nos. 8, 11, 12, 14 and 15, *Megaptera* shows different relative growth from those of *Balaenoptera*. The two genera are clearly separated by means of relative growth. In adult *Balaenoptera* species the head portions show almost same relative growth. However, the relative growth of Nos. 8, 11, 12, 14, 15 and 19 are different in the species each other.

## ACKNOWLEDGEMENTS

I am grateful to Dr. Hideo Omura, the Director of our Institute for his constant direction. And I wish to express my sincere thanks to Dr. Masaru Nishiwaki of our Institute for his kind suggestions and the offering me the data of measurements of whale foetuses in the Antarctic 1954/55 season.

I am also indebted Mr. Kazuo Fujino of our Institute, for the offering me the data of the measurements of 21 fin whale foetuses in the northern Pacific 1954 season.

## REFERENCES

CHITTLEBOROUGH, R. G. (1955a). Aspects of reproduction in the male humpback whale, *Megaptera nodosa* (Bonnaterre). *Aust. J. Mar. Freshw. Res.*, 6 (1): 1-29.

——— (1955b). Puberty, physical maturity, and relative growth of the female humpback whale, *Megaptera nodosa* (Bonnaterre), on the Western Australian coast. *Aust. J. Mar. Freshw. Res.*, 6 (3): 315-27.

——— (1958). The breeding cycle of the female humpback whale, *Megaptera nodosa* (Bonnaterre). *Aust. J. Mar. Freshw. Res.*, 9 (1): 1-18.

FUJINO, K. (1954). On the body proportions of the fin whales caught in the northern Pacific Ocean (I). *Sci. Rep. Whales Res. Inst.*, no. 9: 121-63.

HAMMOND, J. (1950). Measuring growth in farm animals. *Proc. Roy. Soc. Lond.*, 137: 452-61.

HAXLEY, J. S. (1932). *Problems of relative growth.* London, Methuem & Co.

HINTON, M. A. C. (1925). *Report on the paper left by late major Barrett-Hamilton, relating to the whales of South Georgia.* London, Crown Agents for Colonies. (Cited by Laws, 1959).

ICHIHARA, T. (1957). An application of linear discriminant function to external measurements of fin whales. *Sci. Rep. Whales Res. Inst.*, no. 12: 127-89.

KIMURA, S. (1957). The twinning in southern fin whales. *Sci. Rep. Whales Res. Inst.*, no. 12: 103-25.

LABORATORY OF THE ENOSHIMA MARINELAND (1959). Difference of body proportion in growing on the bottle-nosed dolphin. *J. Jap. Zoo and Aqu. Assoc.*, 1 (1): 14-6. (In Japanese).

LAWS, R. M. (1959). The foetal growth rates of whales with special reference to the fin whales, *Balaenoptera physalus* Linn. *Discovery Rep.*, 29: 281–307.

MACKINTOSH, N. A. (1942). The southern stocks of whalebone whales. *Discovery Rep.*, 22: 197–300.

MACKINTOSH, N. A. & WHEELER, J. F. G. (1929). Southern blue and fin whales. *Discovery Rep.*, 1: 257–540.

MATSUURA, Y. & MAEDA, K. (1942). [*Biological investigations of the northern Pacific whales*]. Tokyo, Japan Whaling Fish. Assoc., 59 pp.

MATTHEWS, L. H. (1937). The humpback whale, *Megaptera nodosa*. *Discovery Rep.*, 17: 7–92.

——— (1938a). The sperm whale, *Physeter catodon*. *Discovery Rep.*, 17: 93–168.

——— (1938b). The sei whale, *Balaenoptera borealis*. *Discovery Rep.*, 17: 183–290.

NEMOTO, T. (1959). Food of baleen whales with reference to whale movement. *Sci. Rep. Whales Res. Inst.*, no. 14: 149–290.

NISHIWAKI, M. (1952). Age-determination of Mystacoceti, chiefly blue and fin whales. *Sci. Rep. Whales Res. Inst.*, no. 7: 87–119.

NISHIWAKI, M., HIBIYA, T. & KIMURA, S. (1954). On the sexual maturity of the sei whales of the Bonin waters. *Sci. Rep. Whales Res. Inst.*, no. 9: 165–77.

OHSUMI, S., NISHIWAKI, M. & HIBIYA, T. (1958). Growth of fin whales in the northern Pacific. *Sci. Rep. Whales Res. Inst.*, no. 13: 97–133.

OMURA, H. (1959). Bryde's whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, no. 14: 1–33.

OMURA, H., NISHIMOTO, S. and FUJINO, K. (1952). *Sei whales* (*Balaenoptera borealis*) *in the adjacent waters of Japan*. Tokyo, Fish. Agen. Jap. Gov., 80 pp.

OMURA, H. & SAKIURA, H. (1956). Studies on the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, no. 11: 1–37.

RYDER, J. A. (1885). On the development of the Cetacea, together with a consideration of the probable homologies of the flukes of cetaceans and sirenians. *Bep. U. S. Comm. Fish.*, 427–85.

SHIMIZU, M. (1941). On the relative growth of organs of albino rat. *J. Zool.*, 53 (1): 37–50.

——— (1959). [Relative growth]. Tokyo, 269 pp. (In Japanese)

SLIJPER, E. J. (1958). *Walvissen*. Amsterdam, 465 pp.

THOMPSON, D. A. W. (1952). *On growth and form*. Cambridge Univ. Press., 524 pp.

TRUE, F. W. (1904). The whalebone whale of the western North Atlantic compared with those occurring in European waters, with some observations on the species of the North Pacific. *Smithson. Contr. Knowl.*, 33: 1–332.

WHEELER, J. F. G. (1930). The age of fin whales at physical maturity. *Discovery Rep.*, 2: 403–34.

ZEMSKIY, V. A. (1950). [Certain aspects of the embyology of *Balaenoptera physalus* L. of the Antarctic. *Bull. M. O-va Isp. Prirody. Otd. Biologii*, 55 (6): 15–20.

## APPENDIX I. MEASUREMENTS OF THE ANTARCTIC FIN WHALE FOETUSES

### A. FEMALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 | Serial No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 2.2 | 3.0 | 6.0 | 1.5 | 5.0 | 1.5 | 5.0 | 7.4 | none | 0.3 | 0.2 | 1.0 | 2.2 | 0.7 | 1.4 | 10T 1 |
| 15.2 | 1.7 | 2.9 | 6.6 | 1.0 | 4.0 | 1.4 | 4.45 | 6.6 | none | 0.55 | 0.66 | 1.1 | 1.85 | 0.6 | 0.45 | 12T 60 |
| 17.5 | 2.1 | 4.1 | 7.0 | 1.5 | 6.4 | 1.5 | 6.2 | 8.0 | none | 0.3 | 0.2 | 1.1 | 2.2 | 0.8 | 1.5 | 10T 154 |
| 35 | 3.8 | 5.3 | 12.0 | 2.8 | 9.5 | 2.8 | 11.0 | 16.0 | none | 0.6 | — | 1.7 | 4.3 | 1.2 | 3.2 | 10T 124 |
| 45.5 | 4.2 | 7.6 | 17 | 3.6 | 12.2 | 4.3 | 14.5 | 21.7 | none | 0.8 | 0.7 | 2.3 | 5.3 | 1.5 | 4.3 | 13T 589 |
| 48 | 5 | 8 | 20.5 | 3.5 | 13 | 4.5 | 14.5 | 23 | none | 1.0 | 0.7 | 2.0 | 4.6 | 1.7 | 4.2 | 13T 349 |
| 49 | 7 | 10 | 19 | — | 14.5 | 3.5 | 15 | 25 | none | 1.5 | 1.0 | 3.0 | 6.0 | 1.5 | 4.5 | 10N 331 |
| 50.5 | 6 | 8.6 | 20 | 3.1 | 14 | 4.7 | 16.2 | 24.5 | none | 1.3 | 0.8 | 2.3 | 6.3 | 1.7 | 4.2 | 13T 529 |
| 54.0 | 5.9 | 8.4 | 20.9 | 4.0 | 13.7 | 4.9 | 15.3 | 25.6 | none | 1.4 | 1.4 | 3.5 | 7.1 | 1.9 | 6.0 | 12N 201 |
| 73 | 8.8 | 12.8 | 31.0 | — | 18.1 | 6.1 | 22.1 | 34.6 | none | 1.1 | 1.6 | 3.2 | 9.4 | 2.4 | 7.5 | 12K 885 |
| 73 | 9.0 | 12 | 29 | — | 18 | 5.5 | 21 | 32 | — | 1.5 | 2.0 | 3.5 | 8 | 3 | 9.0 | 10N 101 |
| 75 | 11.0 | 13 | 31 | — | 21 | 5 | 24 | 38 | — | 2.0 | 2.0 | 4.0 | 9 | 3 | 7.0 | 10N 163 |
| 79 | 8.5 | 13 | 32.5 | 6.0 | 20 | 5.5 | 24 | 36 | — | 1.5 | 1.8 | — | 10 | 2.5 | 8.5 | 10T 952 |
| 83 | 10.3 | 14.5 | 35.5 | 6.1 | 20.5 | 7.2 | 25.5 | 38.5 | — | 1.5 | 2.1 | 4.0 | 11 | 2.6 | 8.6 | 13T 165 |
| 89.5 | 11.2 | 15.8 | 33.0 | 6.5 | 22.0 | 6.2 | 27.0 | 39.5 | — | 2.1 | 3.0 | 4.7 | 11.7 | 3.0 | 18.2 | 12K 458 |
| 91 | 11 | 17 | 39 | — | 24 | 7.5 | 29 | 46 | — | 2 | 2.8 | 4.5 | 11 | 3.6 | 10 | 13T 255 |
| 94.5 | 11.5 | 15 | 39 | — | 25.5 | 8.5 | 30 | 47 | — | 2 | 2.1 | 4.3 | 12 | 3.2 | 9.2 | 13T 351 |
| 96 | 14 | 19.5 | 39.5 | — | 25 | 6.0 | 28.5 | 45.5 | — | 2.5 | 2.5 | 4.0 | 11.5 | 3.2 | 10.7 | 10T 367 |
| 108 | 14.5 | 17.5 | 45 | 7.5 | 27.5 | 6.8 | 32.5 | 54.5 | 51 | 3.5 | 2.4 | 5.5 | 12.5 | 3.5 | 9.5 | 10T 97 |
| 110 | 14.5 | 18.5 | 45 | 7.5 | 28 | 9.5 | 34 | 51 | — | 2.5 | — | 4.0 | 13.5 | 3.5 | 10.0 | 13T 198 |
| 116 | 16.5 | 20.0 | 48.5 | 7.7 | 30.5 | 10 | 34 | 52 | — | 3.0 | 2.9 | 5.7 | 16 | 3.7 | 12.5 | 13T 22 |
| 121 | 18 | 21.5 | 53 | — | 31 | 11 | 35 | 55 | 55 | 2.0 | 3.6 | 6.0 | 15.5 | 4.0 | 13.5 | 13T 156 |
| 127 | 16.5 | 20.5 | 51.0 | 8.0 | 34 | 8.5 | 39 | 61.5 | 62 | 3.5 | 3.3 | 6.5 | — | 4.3 | 14 | 10T 1438 |
| 129 | 21 | 25 | 52 | 9 | 32 | 10 | 42 | 62 | — | 4 | 4 | 7 | — | 4.5 | 14 | 10N 288 |
| 132 | 19.5 | 22 | 55 | 9.5 | 34 | 11.5 | 40 | 60 | 60 | 2.0 | 3.4 | 6.5 | 18 | 4.5 | 16 | 13T 134 |
| 137 | 24 | 28 | 56 | 10 | 36 | 11 | 41 | 64 | — | 3 | 5 | 8 | 19 | 5.5 | 15 | 10N 137 |
| 150 | 23.5 | 27.0 | 65 | 9.5 | 35.5 | 9.5 | 45 | 68.5 | 75.0 | 4.5 | 3.5 | — | 19.0 | 5 | 19 | 10T 93 |
| 153 | 25 | 30 | 68 | 9.5 | 42 | 14 | 49 | 76 | 76 | 3.0 | 3.7 | 8.0 | 19.5 | 4.7 | 16 | 13T 133 |
| 159 | 24 | 29 | 69 | 10 | 37 | 12.5 | 42 | 70 | 68 | 4.0 | 5.5 | 8.5 | 22 | 5.5 | 19 | 13T 13 |
| 160 | 29 | 34 | 77 | 10.5 | 43 | 11.5 | 53 | 84.5 | — | 4 | 6 | — | 23.5 | 6.5 | 22.5 | 10T 243 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 166 | 25 | 29 | 72 | — | 40 | 15 | 50 | 77 | 75 | 4 | 4.9 | 9.0 | 23 | 6.0 | 20 | 13T | 129 |
| 167 | 24 | 30 | 70 | 10.5 | 44 | 14.5 | 51.5 | 78 | 79 | 3.5 | 5.2 | 9.5 | 22.5 | 6.0 | 20 | 13T | 40 |
| 172 | 24 | 29 | 73 | 11 | 46 | 15 | 51 | 79 | 81 | 5 | 4.3 | 10 | 25 | 6.2 | 21 | 13T | 969 |
| 177 | 24.5 | 29.5 | 73 | 11 | 45 | 15 | 54 | 82 | 82 | 3 | 4.2 | 8.2 | 25 | 6.0 | 22 | 13T | 183 |
| 185 | 28 | 35 | 78 | 11 | 48 | 14 | 57 | 90 | — | 3 | 6 | — | 25 | 7 | 24 | 10N | 290 |
| 206 | 33 | 42.5 | 92.5 | 13.5 | 49 | 14 | 69 | 104.5 | 99 | 5.0 | 6.5 | 11.5 | 25.0 | 6.8 | 27 | 10T | 368 |
| 210 | 30 | 35.5 | 84.5 | 13 | 52 | 13 | 69 | 103 | 100 | 5.0 | 5.5 | 12 | 24.5 | 6.3 | 29 | 10T | 535 |
| 211 | 32 | 41 | 82 | - | 57 | 16 | 65 | 98 | | 7 | 6 | 12 | — | 6.5 | 26 | 10N | 236 |
| 215 | 34 | 37 | 93 | 13 | 55 | 18 | 64 | 102 | 105 | 3 | 6 | 11 | 32 | 7.2 | 27 | 13T | 587 |
| 222 | 30 | 37 | 104 | 15 | 62 | 18 | 71 | 108 | 102 | 5 | 8 | 12 | 31.5 | 7.8 | 29 | 13T | 8 |
| 222 | 31 | 40 | 93 | — | — | 16 | 70 | 104 | — | 7 | — | — | 27 | 7.5 | 26 | 10N | 144 |
| 226 | 33 | 37 | 92 | — | 59 | 19 | 71 | 107 | 108 | 4 | 6.5 | 12 | 31 | 7.7 | 32.5 | 13T | 44 |
| 227 | 32.5 | 41 | 97 | 14 | — | 14 | 67 | 109 | 104 | 6.5 | 6.0 | 11 | 27.5 | 7.5 | 26.5 | 10T | 307 |
| 262 | 41 | 47 | 106 | 15.5 | 66 | 19.5 | 79 | 122 | 122 | 7 | 7.5 | 15.5 | — | 8.8 | 32 | 13T | 101 |
| 262 | 40 | 45 | 114 | 16 | 65 | 21 | 80 | 117 | 113 | 6 | — | 15 | 37 | 10.5 | 31 | 13T | 554 |
| 268 | 42 | 47 | 111 | 16 | 69 | 21 | 80 | 123 | 119 | 6 | 9.5 | 16 | 36 | 9.2 | 35 | 13T | 1028 |
| 273 | 38 | 45 | 113 | 16 | 80 | 21 | 84 | 128 | — | 9 | 7 | 14 | — | — | — | 10N | 299 |
| 282 | 38 | 49 | 114 | — | 68 | 22 | 84 | 130 | 125 | 7 | 9.5 | 18 | 39.5 | 10 | 37 | 13T | 184 |
| 288 | 48 | 57 | 113 | 18.5 | 74 | 19 | 88 | 131.5 | 128.5 | 8.0 | 7 | 14 | 41.5 | 9.5 | — | 10T | 171 |
| 294 | 53 | 68 | 160 | 21.5 | 91 | 23 | 111 | 176 | 169 | — | 12 | 22 | 51.5 | 12.5 | 47.5 | 13T | 327 |
| 305 | 53.5 | 63 | 149 | 20 | 73.5 | 24 | 96.5 | 150.5 | 145 | 8 | 9.5 | 19 | 48.5 | 12.5 | 44 | 10T | 293 |
| 307 | 45 | 55 | 129 | 17 | 83 | 24 | 97 | 149 | 149 | 13 | 10.2 | 18 | 44 | 10.5 | 41 | 13T | 1337 |
| 307 | 47 | 58 | — | — | 80 | 23 | 95 | 145 | — | 10 | 9 | 17 | — | — | 40 | 10N | 239 |
| 318 | 47 | 57 | 141 | 19 | 81 | 28 | 99 | 153 | 145 | 8 | 12 | 23 | 50 | 11.5 | 41 | 13T | 220 |
| 320 | 49 | 55 | 138 | — | 90 | 26 | 100 | 150 | — | 10 | 13 | 18 | 44 | 12 | 36 | 10N | 166 |
| 322 | 50 | 58 | 141 | 17.5 | 88 | 26 | 99 | 157 | 162 | 12 | 10 | 17 | 48 | 10.7 | 38 | 13T | 353 |
| 361 | 54 | 61 | 149 | 22 | 97 | 31 | 115 | 175 | 171 | 11 | 13 | 22 | 50 | 13 | 44 | 13T | 517 |
| 375 | 53 | 68 | 160 | 21.5 | 91 | 23 | 111 | 176 | 169 | — | 12 | 22 | 51.5 | 12.5 | 47.5 | 10T | 465 |
| 393 | 55 | 63 | 161 | 33 | 96 | 25 | 128 | 193 | — | 10 | 13 | 27 | 56 | 14 | 50 | 10T | 341 |
| 427 | 66 | 76 | 190 | 24 | 112 | 37 | 134 | 204 | 204 | 15 | 14.5 | 30 | 64 | 15 | 55 | 13T | 1454 |
| 431 | 69 | 73 | 180 | 25 | 121 | 37 | 145 | 213 | 204 | 15 | 14 | 26 | 62 | 14.5 | 54 | 13T | 531 |
| 435 | 66 | 76 | 182 | 23.5 | 104 | 25 | 137 | 207 | 210 | 14 | 9.5 | 24 | 60 | 15 | 54.5 | 10T | 840 |
| 441 | 71 | 80 | 192 | 26 | 124 | 36 | 150 | 226 | 225 | 16 | 12 | 28 | 70 | 15 | 57.5 | 13T | 750 |
| 447 | 64 | 76 | 186 | 26 | 118 | 34 | 140 | 213 | 207 | — | 13 | 31 | 43 | 15.5 | 55 | 13T | 1392 |
| 488 | 78 | 90 | 218 | 28 | 130 | 43 | 164 | 249 | 240 | 14 | 15 | 34 | 74 | 16.5 | 56 | 13T | 1551 |
| 495 | 72 | 90 | 216 | 27 | 139 | 42 | 168 | 255 | 247 | 14 | 17 | 34 | 81 | 18 | 55 | 13T | 1513 |
| 527 | 87 | 99 | 232 | 28 | 132 | 45 | 166 | 252 | 243 | 15 | 20.5 | 32 | 87 | 19 | 63 | 13T | 1486 |

## APPENDIX I. MEASUREMENTS OF THE ANTARCTIC FIN WHALE FOETUSES

### B. MALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 | Serial No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.0 | 1.1 | 1.65 | 4.7 | 0.9 | 3.2 | 1.3 | 3.4 | 5.1 | none | 0.65 | none | 0.7 | 1.5 | 0.5 | 0.3 | 11T 87 |
| 24.7 | 2.1 | 4.5 | 8.8 | 1.8 | 6.3 | 2.5 | 7.2 | 11.8 | none | 1.8 | 0.4 | 1.8 | 3.5 | 1.0 | 2.0 | 12T 355 |
| 34 | 4.5 | 6.5 | 14 | — | 10 | 3.0 | 10.5 | 16.5 | none | 2.5 | 1.0 | 2.5 | 4.0 | 1.0 | 3.0 | 10N 240 |
| 34 | 4.1 | 6.7 | 13.8 | 2.1 | 7.8 | 3.0 | 9.4 | 15.2 | none | 2.3 | 0.5 | 2.0 | 5.0 | 1.2 | 2.8 | 13T 9 |
| 42 | 5.9 | 7.5 | 16 | 3.5 | 11.3 | 3.2 | 11.8 | 18.1 | none | 2.9 | 0.8 | 2.2 | 5.3 | 1.4 | 3.9 | 10T 100 |
| 50 | 6.0 | 8.5 | 19 | — | 14 | 4.5 | 15 | 24 | none | 3.0 | 1.0 | 2.5 | 6.0 | 2.0 | 5.0 | 10N 293 |
| 58.0 | 6.3 | 8.9 | 23.6 | 4.3 | — | 5.1 | 16.8 | 26.4 | none | 4.3 | 1.5 | 3.5 | 7.8 | 2.2 | 6.2 | 12N 164 |
| 61 | 6.5 | 10 | 24 | 4.2 | 17.2 | 6.1 | 19 | 30 | none | 4 | 1.4 | 3.4 | 7.4 | 1.9 | 6.0 | 13T 318 |
| 61 | 8 | 11 | — | 3 | 17.8 | 5.2 | 20.3 | 29 | none | — | 1.3 | 3 | 8 | 2.3 | 7.5 | 10T 410 |
| 63 | 8.0 | 10 | 25 | — | 16 | 4.5 | 20 | 29 | none | 4.0 | 1.0 | 3.0 | 7.0 | 2.5 | 6.0 | 10N 1132 |
| 64 | 8.0 | 9 | 25 | — | 19 | 5.0 | 21 | 32 | none | 4.5 | 1.5 | 3 | 8 | 2.0 | 6.5 | 10N 54 |
| 69.3 | 8.0 | 10.2 | 26.5 | 4.7 | 19.7 | 5.5 | 21.8 | 34.1 | none | 4.0 | 1.6 | 3.6 | 9.0 | 3.1 | 6.4 | 12N 1335 |
| 71 | 6.5 | 11.5 | 27 | 4.5 | 18 | 4.8 | 22 | 33.5 | none | — | 1.3 | 2.5 | 8.0 | 2.5 | 7 | 10T 1387 |
| 72 | 8 | 10.5 | 28 | 5 | 20 | 4.7 | 22.5 | 34 | none | 4.5 | 1.4 | 3.0 | 8.5 | 2.5 | 6.8 | 10T 1438 |
| 77 | — | — | — | — | 21 | 7.8 | — | — | none | — | — | — | — | — | 8.5 | 13T 387 |
| 79 | 11 | 14 | 33 | — | 20 | 5.0 | 24 | 36 | none | 5.0 | 2 | 4 | 9 | 2.8 | 8 | 10T 330 |
| 88 | 11 | 15 | 34 | — | 24 | 6.0 | 26 | 42 | — | 6.5 | 2.0 | 5.0 | 10.5 | 3.0 | 8.0 | 10N 957 |
| 91.5 | — | 16.5 | 35.5 | 5.1 | 25.0 | 7.0 | 27.0 | 43 | 40.5 | 6.5 | 2.5 | — | 12.0 | 3.2 | 9.0 | 10T 16 |
| 97 | 14 | 16 | 38 | 6.0 | 25.5 | 7.0 | 31 | 47 | — | 6.0 | 3.0 | 4.5 | — | 3.0 | — | 10N 516 |
| 97 | 14 | 17.5 | 40 | — | 24 | 8.0 | 29 | 46 | — | 7 | 2.5 | 4.3 | 13 | 3.4 | 10.3 | 13T 67 |
| 99 | 13.5 | 16.5 | 39 | 7.3 | 24.5 | 7.0 | 29 | 48 | 50 | 6.5 | 2.0 | 5.0 | 11.5 | 3.5 | 9.5 | 10T 316 |
| 102 | 12 | 17 | 43 | 7 | 26 | 9.0 | 31.5 | 50 | 52 | 7.5 | 3.0 | 4.5 | 13.5 | 3.5 | 11.0 | 13T 4 |
| 107 | 13 | 17 | 39.5 | 7 | 28 | 7.5 | 31 | 51 | — | 7.5 | 2.5 | 5 | — | 3.5 | 11.5 | 10T 240 |
| 109 | 14 | 18 | 46 | 7.5 | 26 | 9 | 33 | 49 | — | 6 | 2.8 | 5.3 | 15 | 3.4 | 11.5 | 13T 610 |
| 116 | 14 | 18.5 | 48 | 5.8 | 38.1 | 11 | 34 | 65 | 64 | 7 | 3.2 | 6.0 | 15.5 | 3.5 | 12.5 | 13T 124 |
| 118 | 14.5 | 21 | 51 | 8.5 | 30 | 11 | 36 | 57 | 61 | 8 | 3.2 | 6.0 | 16.5 | 4.1 | 14 | 13T 23 |
| 138 | 19 | 24 | 56 | 8.5 | 34 | 9.5 | 44.5 | 70.5 | — | 10.5 | — | — | 16.5 | 4.5 | 15.5 | 10T 369 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 145 | 20.5 | 25.0 | 62 | 10.5 | 39 | 10 | 42.5 | 69.5 | 73 | 10.5 | 5 | 7.5 | 18 | 5 | 15.5 | 10T | 130 |
| 150 | 20 | 26 | 65 | 10.5 | 38 | 14 | 46 | 69 | 69 | 10 | 4.5 | 8 | 21 | 5 | 18 | 13T | 77 |
| 155 | 21 | 27 | 67 | 11 | 38 | 12 | 46 | 72 | 69 | 11 | 3.5 | 7.5 | 15.5 | 5.5 | 17 | 13T | 585 |
| 164 | 25 | 31.5 | 72 | 11.5 | 38.5 | 11 | 48 | 75 | 82 | 12 | 5.5 | 9 | 20 | 5.5 | 19 | 10T | 165 |
| 167 | 23 | 29 | 70 | 12 | 39.5 | 12 | 49 | 80 | 80 | 11 | 4.2 | 8 | 22 | 5.5 | 14 | 13T | 553 |
| 176 | 28 | 32 | 78 | 10 | 45 | 14 | 52 | 84 | — | 14 | 5.5 | 9 | 26 | 5.5 | 20 | 10N | 508 |
| 188 | 28 | 34.5 | 75 | 12.5 | 41 | 12 | 54.5 | 85 | 89 | 13 | 5.5 | 10 | 24 | 6 | 22 | 10T | 188 |
| 192 | 30 | 39 | 83 | 12 | 53 | 15 | 55 | 85 | — | 12 | 7 | — | 28 | 8 | 25 | 10N | 333 |
| 196 | 25.5 | 32.5 | 83 | 12.5 | 45.5 | 13 | 58 | 92.5 | 94 | 15 | 5.5 | 11.0 | 24.5 | 6 | 16 | 10T | 1177 |
| 208 | 27 | 36 | 90 | 13 | 50 | 16 | 57 | 96 | 94 | 13 | 5.0 | 10 | — | 6.5 | 22 | 13T | 76 |
| 212 | 31 | 36 | 86 | 13 | 52 | 17 | 64.5 | 99 | 102 | 145 | 5.5 | 12 | 29.5 | 6.8 | 22 | 13T | 312 |
| 219 | 29 | 36 | 89 | 13 | 57 | 17 | 65 | 104 | 100 | 16 | 5.5 | 12 | 30 | 7.8 | 28 | 13T | 400 |
| 239 | 36 | 45 | 106 | 13.5 | 65 | 21 | 76 | 107 | 102 | 18 | 7.5 | 13.5 | 34 | 7.9 | 32 | 13T | 160 |
| 255 | 42 | 45 | 107 | 15 | 64 | 21 | 78 | 120 | 120 | 17 | 8 | 14 | 38 | 9.5 | 33 | 13T | 10 |
| 265 | 40 | 46 | 113 | 18 | 74 | 25 | 86 | 130 | — | 19 | 8.7 | 12 | 38 | 9 | 32 | 13T | 1208 |
| 271 | 37 | 54 | 120 | 15 | 66 | — | 79 | 124 | — | 19 | 10 | 15 | 35 | 8 | — | 10N | 391 |
| 282 | 42 | 50 | 119 | — | 70 | 24 | 90 | 138 | 144 | 19 | 7.5 | 16 | 41 | 9.5 | 34 | 13T | 1 |
| 295 | 47 | 58 | 136 | 18 | 76 | 22 | 98 | 144 | 139 | 20 | 10 | 21 | 44 | 11 | 43 | 10T | 99 |
| 297 | 55 | 47 | 127 | 16.5 | 78 | 28 | 84 | 141 | 136 | 20 | 8 | 16 | 39 | 10.2 | 36 | 13T | 154 |
| 315 | 46 | 59 | 136 | 18 | 82 | 22.5 | 100 | 170 | 166 | 23 | 10.5 | 16 | 40 | 11.5 | 36.5 | 10T | 313 |
| 345 | 55 | 67 | 155 | 30 | 89 | 22.5 | 107 | 160 | 170 | 23 | 12 | 22 | 48 | 12.5 | 42 | 10T | 99 |
| 354 | 59 | 66 | 147 | 21 | 90 | 31 | 110 | 165 | 162 | 22 | 11 | 20 | 51 | 12 | 43 | 13T | 169 |
| 358 | 57 | 66 | 154 | 21 | 88 | 30 | 122 | 167 | 172 | 20 | 12.5 | 23 | 49 | 11.5 | 42 | 13T | 1057 |
| 361 | 56 | 68 | 151 | 21 | 92 | 31 | 120 | 175 | 170 | 22 | 10.5 | 24 | 51 | 12 | 44 | 13T | 395 |
| 370 | 56 | 63 | 155.5 | 21 | 100 | 24 | 123 | 183 | 174 | 22.5 | — | 23.5 | — | — | 39 | 10T | 273 |
| 377 | 57 | 69 | 176 | 23 | 95 | 31 | 102 | 187 | 185 | 24 | 13 | 22 | 61 | 13 | 43 | 13T | 856 |
| 400 | 57 | 70 | 165 | 21 | 110 | — | 115 | 180 | — | 30 | 9 | 24 | 55 | 15 | — | 10N | 335 |
| 402 | 49 | 68 | 162 | — | — | 26 | 125 | 187 | — | 32 | — | — | — | 14 | 48 | 10T | 480 |
| 420 | 64 | 80 | 180 | 22 | 113 | 36 | 137 | 208 | 206 | 30 | 12 | 27 | 65 | 14.5 | 44 | 13T | 1530 |
| 485 | 68 | 79 | 215 | 29 | 121 | 46 | 159 | 237 | 232 | 35 | 13.5 | 30 | 74 | 17.5 | 55 | 13T | 1400 |
| 504 | 71 | 96 | 210 | — | 117 | 34 | 170 | 255 | 252 | 40 | 16.5 | — | 77 | 18 | 73 | 10T | 1484 |

## APPENDIX II. MEASUREMENTS OF THE NORTHERN PACIFIC FIN WHALE FOETUSES

### A. FEMALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 | Serial No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17.9 | 1.8 | 2.8 | 7.0 | 1.5 | 4.9 | 1.8 | 5.5 | 8.3 | none | 0.48 | 0.14 | 1.1 | 2.5 | 0.80 | 1.3 | 56Ky 516 |
| 18.3 | 2.1 | 3.1 | 8.0 | 1.4 | 4.4 | 1.6 | 5.3 | 8.0 | none | 0.3 | 0.2 | 1.1 | 2.4 | 0.8 | 0.95 | 54K 516 |
| 19.6 | 2.1 | 3.0 | 7.8 | 1.3 | 5.3 | 1.8 | 6.6 | 8.6 | none | 0.7 | 0.15 | 1.0 | 2.4 | 0.7 | 0.8 | 59Ky 27 |
| 32.3 | 3.0 | 4.5 | 12.7 | — | 8.8 | — | 10.2 | 15.3 | none | 1.1 | 0.6 | 2.0 | — | — | — | 54K 611 |
| 35.7 | 3.6 | 6.0 | 9.9 | 2.8 | 9.7 | 2.9 | 12.0 | 17.4 | none | 0.65 | 0.5 | 1.9 | 4.5 | 1.3 | 2.7 | 59Ky 89 |
| 52.5 | 6 | 8.5 | 21 | 4 | 13 | 4.5 | 15.5 | 25.5 | — | 1.5 | 1.0 | 2.5 | 6 | 1.7 | 5.2 | 54K 391 |
| 56 | 7.7 | 9.5 | 23.5 | — | 14 | — | 18 | 27 | none | 1 | 1.6 | 3 | 6.5 | 2.3 | — | 54B 153 |
| 67.5 | 7.8 | 11.5 | 28.5 | 4.8 | 16.5 | — | 22.3 | 32.0 | none | 1.8 | 1.5 | 3.5 | 8.0 | 2.3 | — | 57Ky 688 |
| 77 | 10 | 13.5 | 31 | — | 20.5 | — | 24.5 | 38 | none | 2 | 1.8 | 4 | 11 | 2.7 | — | 55Ky 4 |
| 80 | 11 | 14 | 32 | — | 21 | — | 26 | 40 | none | 2 | 1.5 | 5 | 9.5 | 2.8 | — | 54B 38 |
| 88 | 10 | 14.5 | 36 | 6 | 21 | — | 26 | 41 | — | 2 | 2.0 | 4 | 11.5 | 3.0 | — | 54K 899 |
| 90 | 14 | 16.5 | 36 | 7 | 24 | — | 29 | 45 | none | 2.5 | 2.5 | 4 | 13 | 3.5 | — | 54K 30 |
| 93 | 11 | 15 | 37.5 | 6.5 | 24 | 8 | 29.5 | 45 | — | 2 | 2.0 | 4.5 | 13 | 3 | 10 | 54K 602 |
| 94 | 12.0 | 16.5 | 39.0 | 6.5 | 25 | — | 30 | 46 | — | 3.0 | 2.0 | 3.8 | 13.5 | 4 | 10.5 | 54K 132 |
| 102 | 15 | 19 | 45 | 7 | 26 | 9.5 | 31 | 49 | — | 2.0 | 3.0 | 5.0 | 15 | 3.5 | 12 | 54K 600 |
| 104 | 17.5 | 21 | 48 | 8 | 28 | — | 34 | 54 | — | 3 | 6.5 | 6 | 16 | 4 | — | 54K 145 |
| 106 | 15 | 19 | 43 | 7 | 28 | — | 33 | 49 | — | 2.5 | 2.0 | 5.0 | 13.5 | 3.5 | — | 54K 455 |
| 115 | 16.0 | 21.5 | 51 | 8.5 | 27.5 | — | 32.5 | 50.0 | 50.0 | 3.0 | 3.4 | 5.5 | 15.0 | 3.7 | 13.5 | 54K 322 |
| 119 | 17.5 | 21.5 | 52.0 | 8.5 | 27.3 | — | 37.0 | 58.0 | 63.0 | 4.3 | — | 7.0 | 16.5 | 4.0 | — | 57K 580 |
| 126 | 18 | 21 | 50 | 8 | 31 | — | 40 | 61 | 65 | 3.5 | 3.5 | 5.5 | 15 | 4.7 | — | 54K 7 |
| 128 | 18 | 22 | 51 | 9 | 32 | — | 39 | 62 | — | 3.5 | 4.0 | 7.0 | 18.0 | 4.0 | 14.0 | 54K 139 |
| 129 | 19 | 23.5 | 54 | — | 33 | — | 40 | 62 | 64 | 2 | 2.9 | 4.8 | 16 | 4.5 | — | 54B 167 |
| 131 | 20 | 25 | 56 | 9 | 35 | — | 39 | 60 | 57 | 3.5 | 3 | 6 | 18 | 4.5 | — | 54K 348 |
| 136 | 18 | 28.5 | 57 | 9 | 39 | — | 43 | 66 | 66 | 4.0 | 3.5 | 5.5 | 18 | 4.5 | — | 54K 29 |
| 137.5 | 20 | 23 | 58 | 9.5 | 36 | — | 43 | 61 | 65 | 2.5 | 4.0 | 6.5 | — | — | — | 56Ky 442 |
| 139 | 18 | 22 | 59.5 | 9.0 | 38 | — | 46 | 71 | 68 | 3.5 | 4.5 | 5.5 | 16.5 | 4.5 | 18 | 54K 471 |
| 144 | 18 | 25.5 | 62 | 9.5 | 36 | 12 | 42.5 | 65 | 70 | 4.5 | 4.5 | 7 | 19 | 5.3 | 19 | 54K 907 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 144 | 20 | 27 | 63 | 10 | 39 | 14 | 43 | 68 | 68 | 5 | 4.0 | 6.0 | 21 | 5 | 16 | 54K | 372 |
| 148 | 19 | 27 | 65 | 10.5 | 38.5 | 12.5 | 46 | 72 | 72 | 4.5 | 3.5 | 6 | 18 | 5 | 16 | 54K | 911 |
| 151 | 21 | 27 | 66 | 9.0 | 35.5 | — | 44 | 70 | 70 | 5.0 | 4.3 | 8.0 | 22 | 5.4 | 17 | 54K | 130 |
| 152 | 21 | 27 | 62 | 10.5 | 35.5 | — | 46 | 70.5 | 70.5 | 4 | 4.0 | 8.0 | — | — | — | 54K | 52 |
| 156 | 21 | 27 | 77 | — | 37 | 13 | 46 | 73 | 72 | - | 5.0 | 10 | 24 | 5.5 | 18 | 54K | 487 |
| 157 | 25 | 29 | 70 | 11.5 | 37 | — | 48 | 71 | — | 4 | 3.5 | 8 | — | — | — | 54K | 478 |
| 158 | 22.5 | 27 | 65 | 10.5 | 40.5 | — | 44.5 | 70 | 70 | 4.5 | 3.5 | 6.5 | 22 | 5.0 | — | 54K | 129 |
| 158 | 23 | 29 | 69 | 10 | 38 | 14 | 47 | 74 | 71 | 4 | 4.5 | 7.5 | 23 | 5.5 | 20 | 54K | 757 |
| 160 | 20 | 26 | 67 | 10.5 | 41 | 13 | 47 | 73 | 71 | 4.5 | 3.0 | 7.0 | — | — | 18 | 54K | 923 |
| 168 | 26 | 31 | 76 | 11.0 | 44 | - | 49 | 81 | 77 | 5 | 3.5 | 8.0 | 24.5 | 6.3 | 22 | 54K | 386 |
| 169 | 24 | 29 | 70 | 11.0 | 44 | - - | 52.0 | 79.0 | 76 | 4.5 | 4.5 | 8.5 | 21.0 | 5.9 | 23 | 54K | 382 |
| 171 | 25 | 31 | 71 | 10.5 | 46 | 14.5 | 52 | 80.5 | 77 | 5.0 | 6.5 | 9.0 | 21 | 6.5 | 24.5 | 54K | 627 |
| 176 | 28 | 34 | 77 | 10.0 | 45 | — | 55 | 86 | 82 | 4.5 | 5.0 | 9.5 | 23 | 6.0 | 20.0 | 54K | 344 |
| 179 | 29 | 35 | 77 | — | 46 | — | 54 | 85 | 85 | 5 | 6.0 | 8.5 | 22 | 6.2 | — | 54B | 67 |
| 180 | 27 | 33.5 | 79 | — | 45 | 14.5 | 53.5 | 86 | 81.5 | 5 | 4.0 | 8.0 | 25 | 6.5 | 20.5 | 54K | 574 |
| 180 | 27 | 32 | 77 | 11 | 49 | 17 | 57 | 86 | 79 | 5 | 4.0 | 8.0 | 27 | 7.0 | 19 | 54K | 945 |
| 182 | 25 | 30 | 74 | 12 | 48 | — | 59 | 89 | — | 5 | 4.5 | 9.0 | 25 | 6.0 | — | 54K | 596 |
| 185 | 28 | 34 | 80 | 9 | 47 | — | 55 | 87 | 84 | 5.5 | 5.0 | 9.0 | 26 | 6.5 | 22.0 | 54K | 127 |
| 201 | 27 | 35 | 87 | — | 51 | 14.5 | 61 | 93 | 88 | 5 | 5.0 | 10.5 | — | 6.5 | — | 56Ky | 187 |
| 223.5 | 36 | 43.5 | 101.5 | 14.0 | 56 | — | 66 | 99 | 99 | 5 | 6.5 | 13.5 | 31.5 | 8.8 | — | 57Ky | 521 |
| 228 | 30 | 41 | 100 | — | 56 | 16 | 68 | 104 | 99 | 6 | 5 | 13 | — | 8.0 | — | 56Ky | 186 |
| 237 | 35 | 40 | 103 | 15 | 61 | — | 73 | 110 | — | 7 | 7 | 13 | 35 | 8.5 | — | 54K | 383 |
| 244 | 38 | 43 | 103 | 14 | 61 | 22 | 75 | 116 | 110 | 7 | 6 | 14 | 37 | 8.5 | 29 | 54K | 976 |
| 273 | 43 | 50 | 118 | 16 | 73 | 22 | 83 | 130 | 125 | 8 | 9 | 16 | — | — | 31 | 54K | 922 |
| 288 | 44 | 50 | 124 | 18 | 74 | 23 | 90 | 137 | — | 8 | 7.5 | 15 | 40 | 10 | 39 | 54K | 902 |
| 295 | 40 | 51 | 124 | 19 | 75 | — | 92 | 144 | 139 | 9 | 8 | 15 | 37 | 10 | — | 54B | 654 |
| 300 | 47 | 57 | 138 | 14 | 73 | — | 83 | 128 | 124 | 8 | 9 | 17 | 39 | 10 | — | 54B | 320 |
| 320 | 47 | 53 | 137 | 13 | 78 | — | 94 | 162 | 162 | 11 | 7 | 18 | 44 | 11 | — | 54B | 436 |
| 348 | 56 | 64 | 155 | 22 | 92 | — | 102 | 155 | 155 | 11 | 10 | 19 | 48 | 13 | — | 54B | 688 |
| 358 | 55 | 68 | 163 | 21 | 96 | 36 | 120 | 180 | — | 12 | 9 | 20 | 56 | 13 | 47 | 54K | 950 |
| 370 | 58 | 71 | 164 | — | 100 | — | 125 | 190 | 185 | 10 | 12 | 27 | 55 | 14 | — | 54B | 1054 |
| 427 | 70 | 87 | 207 | 25 | 120 | — | 135 | 213 | 204 | 16 | 16 | 33 | 61 | 17 | — | 54B | 685 |
| 480 | 80 | 87 | 200 | - | 130 | — | 155 | 240 | 235 | 15 | 14.5 | 26 | 68 | 16 | — | 54B | 890 |

## APPENDIX II. MEASURE OF THE NORTHERN PACIFIC FIN WHALE FOETUSES

### B. MALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 | Serial No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26.8 | 2.5 | 4.1 | 11.1 | 2.2 | 6.4 | 2.0 | 7.8 | 11.6 | none | 1.7 | 0.22 | 1.6 | 3.7 | 1.1 | 1.7 | 54K 918 |
| 27.5 | 2.6 | 3.2 | 11.8 | — | 7.0 | 2.1 | 7.8 | 12.0 | none | 2.0 | 0.3 | 1.3 | 3.0 | 1.1 | — | 56Ky 137 |
| 35.7 | 3.7 | 6.0 | 14.2 | 2.6 | 9.6 | 3.3 | 10.6 | 16.5 | none | 2.1 | 0.57 | 1.6 | 4.9 | 1.4 | 3.4 | 56Ky 51 |
| 65 | 8 | 11 | 27 | — | 16 | 7 | 19.5 | 31 | — | 4.5 | 1.2 | 2.5 | 8.8 | 2.2 | 6.5 | 56K 594 |
| 65 | 6.5 | 10.5 | 28 | 4.5 | 17 | — | 20.5 | 32.5 | — | 4.0 | 1.4 | 3.5 | 8.5 | 2.3 | 6.3 | 54K 79 |
| 66.5 | 8.5 | 12.5 | 28 | 5.0 | 18.5 | — | 22.0 | 35 | — | 5.0 | 1.6 | 3.5 | 9.0 | 2.4 | 7.3 | 54K 78 |
| 67 | 9 | 10.5 | 26 | — | 16 | — | 19 | 32 | — | 5 | 1.8 | 4 | 8 | 2.3 | — | 54K 63 |
| 68 | 7 | 10 | 26 | 4.5 | 18 | 6 | 22 | 33 | — | 4 | 1.5 | 3 | 8 | 2.3 | 6.3 | 54K 450 |
| 72 | 8 | 11 | 29 | 5 | 18 | 11 | 22 | 36.5 | — | 5 | 2 | 4.5 | 9.5 | 2.5 | 8.5 | 54K 413 |
| 76.5 | 9.5 | 13 | 30 | 5.8 | 18.5 | — | 23 | 36 | — | 5.5 | 1.6 | 4.0 | 9.5 | 2.6 | — | 54K 36 |
| 78.5 | 10.5 | 13 | 30 | 5.8 | 18.5 | — | 25.2 | 40 | none | 5.1 | 1.6 | 4.8 | 10.5 | 2.8 | — | 56Ky 587 |
| 79 | 8.0 | 12.5 | 31.5 | 5.5 | 20.0 | — | 24 | 38 | — | 5.5 | 1.8 | 4.0 | 10.0 | 2.5 | 8.5 | 54K 32 |
| 88 | 11.0 | 15 | 38 | 6.2 | 22 | — | 27.5 | 42.0 | 42.0 | 5.5 | 2.2 | 4.0 | 12.0 | 3.4 | 10.3 | 54K 57 |
| 89.8 | 12.1 | 15.8 | 39.2 | 4.0 | 21.5 | — | 27.5 | 43.5 | 51.0 | 6.0 | 2.8 | 6.0 | 12.0 | 3.2 | — | 56Ky 598 |
| 95 | 14 | 17 | 38 | — | 25 | — | 30 | 48 | — | 8 | 2.6 | 4.5 | 11.5 | 3.3 | — | 54B 125 |
| 96 | 10.6 | 15 | 38.5 | 6.8 | 21.5 | — | 28.5 | 44.5 | 51.5 | 6.5 | 2.3 | 6.0 | — | — | — | 56Ky 449 |
| 97 | 11.0 | 15 | 39 | 7 | 25 | 8 | 29 | 47 | — | 6 | 2 | 4.5 | 1 | 3 | 10 | 54K 750 |
| 98 | 14.5 | 18 | 39 | 7 | 26 | — | 30.5 | 49 | — | 6.5 | 2.5 | 4.0 | 12.5 | 3.5 | — | 54K 31 |
| 108 | 15.0 | 18 | 46 | 7 | 26 | 8 | 31 | 48 | 48 | 6 | 2.5 | 5 | 14 | 3.5 | 13 | 54K 756 |
| 113 | 17 | 21 | 48 | 8 | 27 | — | 34 | 52 | — | 7 | 3.5 | 6 | 16 | 3.5 | — | 54K 465 |
| 118 | 15 | 19 | 46.5 | 8 | 31 | 10 | 38 | 56 | (60) | 8.0 | 3.5 | 7.5 | 15 | 3.7 | 13 | 54K 479 |
| 119 | 17.5 | 21.5 | 52.0 | 8.5 | 27.3 | — | 37 | 58 | 63 | 4.3 | — | 7.0 | 16.5 | 4.0 | — | 56K 580 |
| 122 | 19 | 23 | 55 | — | 33 | — | 38 | 61 | 6 | 9 | 4.5 | 7 | 17 | 5 | — | 54B 199 |
| 132 | 17 | 23 | 56 | 9 | 32 | — | 41 | 61 | 6 | 8 | 3.5 | 7.5 | 19 | 5 | — | 54K 761 |
| 133 | 17 | 22 | 54 | 8 | 35 | 12 | 41 | 64 | 6 | 9 | 3 | 6.5 | 18 | 4.5 | 15 | 54K 737 |
| 136 | 20 | 24 | 55 | — | 33 | — | 40 | 66 | 6 | 11 | 3 | 5 | 17 | 4.6 | — | 54B 145 |
| 137 | 22 | 27 | 59 | — | 36 | — | 39 | 64 | 68 | 11 | 3.8 | 6 | 18 | 5 | — | 54B 183 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 140 | 21 | 26 | 58 | — | 38 | — | 42 | 74 | 74 | 9 | 4.5 | 6.5 | 17 | 4.5 | — | 54B 1022 |
| 142 | 22 | 26.5 | 61.0 | 9.3 | 36.5 | — | 41.5 | 66.0 | 66 | 10 | 4.7 | 7.5 | 20.2 | 5.0 | — | 56Ky 646 |
| 146 | 20 | 26 | 62 | — | 35 | — | 40 | 67 | 63 | 11 | 4 | 6 | 19 | 5.2 | — | 56K 114 |
| 149 | 19 | 24.5 | 56 | — | 31 | — | 41 | 65 | 71 | 11 | 4.5 | 7 | 16 | 4.5 | — | 54B 103 |
| 155 | 20 | 26 | 63 | 10.5 | 41 | 13 | 49 | 78 | 75 | 10 | 3.5 | 8 | 23 | 5.5 | 19 | 54K 541 |
| 159 | 23.5 | 27.5 | 68 | - | 44 | — | 49 | 78 | 78 | 8 | 5 | 8 | 20 | 5.3 | — | 55Ky 3 |
| 166 | 26 | 32 | 74 | — | 42 | — | 52 | 77.5 | 73 | — | 3 | 6.5 | 21.5 | 5.5 | — | 55Ky 18 |
| 170 | 23.0 | 30 | 72 | 11.0 | 38.0 | 16 | 52 | 80 | 80 | 11.0 | 4.5 | 7.5 | 23.0 | 6.0 | 20 | 56Ky 729 |
| 173 | 26 | 31.5 | 77 | 11.5 | 43 | 15 | 50 | 80 | 77 | 11 | 4 | 9.0 | 25 | 6 | 21 | 54K 567 |
| 176.5 | 27.5 | 31.0 | 74.5 | 11.5 | 43.5 | — | 55 | 84.5 | 86.5 | 13.5 | 4 | 11.5 | — | — | — | 56Ky 586 |
| 180 | 27 | 33 | 79 | 12 | 44 | 15 | 52 | 84 | 81 | 12 | 4.5 | 9 | 25 | 6 | 21 | 54K 567 |
| 181 | 23.0 | 31 | 75 | — | 45 | 16 | 55 | 87 | 85 | 13 | 6 | 10 | 23 | 6 | 22 | 54K 754 |
| 186 | 24 | 33 | 80 | 12 | 48 | 15 | 53 | 85 | 82 | 11 | 5 | 11 | 25 | 6.5 | 20 | 54K 730 |
| 186 | 26 | 33 | 80 | — | 46 | 13 (21) | 58 | 90 | 87 | 12 | 6 | 10 | 17.5 | 6 | 21 | 56Ky 246 |
| 188 | 27 | 35 | 86 | — | 50 | 16 | 58 | 86 | 83 | 12 | 6 | 10 | 19.5 | 6.5 | 24 | 56Ky 246 |
| 198 | 28 | 35 | 84 | 12.5 | 51.5 | 18 | 62 | 95.5 | 95.5 | 14 | 5.5 | 9.5 | 26 | 6.8 | 23.5 | 54Ky 889 |
| 206 | 31 | 37 | 90 | — | 53 | — | 64 | 98 | 92 | 14 | 5.5 | 10 | 28 | 3.5 | — | 56Ky 776 |
| 220 | 33 | 40 | 100 | 14 | 54 | — | 64 | 125 | 100 | 16 | 7 | 12 | 29 | 8 | — | 54B 646 |
| 246 | 42 | 48 | 109 | 14 | 63 | 21 | 76 | 122 | 118 | 14 | 7 | 13 | 37 | 6 | 31 | 56Ky 947 |
| 254 | 35 | 44 | 107 | 15 | 65 | — | 78 | 120 | 117 | 19 | 6.5 | 15 | 38 | 9.5 | 32 | 56Ky 444 |
| 255 | 41 | 46 | 108 | 16 | 65 | 21 | 76 | 125 | 120 | 21 | 9.8 | 15 | 34 | 9 | 33 | 56Ky 936 |
| 268 | 41 | 48 | 115 | 17 | 70 | 21 | 81 | 125 | 120 | 20 | 7.5 | 18 | 39 | 10 | 28 | 54K 918 |
| 284 | 44 | 49 | 122 | 16 | 73 | 25 | 86 | 137 | 130 | 18 | 10 | 15 | 40 | 10 | 40 | 54K 615 |
| 291 | 40 | 51 | 127 | 17.5 | — | — | — | — | — | — | — | — | 44 | 11 | — | 54K 948 |
| 295 | 35 | 48 | 156 | 18 | 70 | — | 91 | 119 | 119 | 20 | 8 | 17 | 38 | 11 | — | 54B 428 |
| 296 | 46 | 51 | 126 | 19 | 80 | 25 | 100 | 146 | 149 | 20 | 9.5 | 15 | 40 | 11 | 34 | 56Ky 934 |
| 300 | 45 | 53 | 130 | 18 | 77 | 25 | 91 | 142 | 138 | 23 | 10 | 19 | 45 | 11 | 42 | 54K 738 |
| 311 | 48 | 58 | 141 | 20 | — | — | — | 170 | 177 | 20.7 | 8 | 22 | 46 | 11 | — | 54K 687 |
| 346 | 56 | 67 | 158 | — | 96 | — | 114 | 166 | 162 | — | 11 | 22 | 52 | 13 | — | 54B 1056 |
| 350 | 54 | 65 | 155 | — | 97 | — | 113 | 167 | 167 | 24 | 11 | 22 | 49 | 12 | — | 54B 954 |
| 357 | 58 | 72 | 165 | — | 100 | — | 114 | 182 | 175 | 22 | 12 | 18 | 51 | 13 | — | 54B 1057 |

## APPENDIX III. MEASUREMENTS OF ADULT MINKE WHALES FROM THE COAST OF JAPAN

### A. FEMALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 478 | 58 | 74 | 197 | 24.5 | 147 | 34 | 128 | 222 | 273 | 11 | 22 | — | 74 | 18 | 68 |
| 512 | 59 | 82 | 213 | 24 | 138 | — | 153 | 276 | 288 | — | 24 | 38 | 76 | 19 | 68 |
| 578 | — | 92 | — | — | — | 39.5 | — | — | — | — | 20.5 | 29 | 59.5 | 20.5 | 81 |
| 639 | — | — | 245 | — | 139 | — | 171 | 318 | 353 | 22 | — | — | 75 | — | 65 |
| 790 | 100 | 118 | 295 | — | 238 | 59 | 270 | 437 | 460 | 20 | 37 | 60 | 119 | 29 | 120 |

### B. MALES

| No. 1 | No. 3 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 | No. 11 | No. 12 | No. 13 | No. 14 | No. 15 | No. 17 | No. 19 | No. 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 486 | 54 | 81 | — | — | — | 34 | — | — | — | — | 17 | 28 | 46 | 16 | 68 |
| 486 | 62 | 73 | 186 | 27 | 139 | 40 | 148 | 228 | 263 | — | 17 | 39 | 78 | 19 | 74 |
| 514 | 62 | 76 | 135+No. 17 | — | 142 | — | 133 | 242 | 298 | — | — | — | — | — | — |
| 522 | 65 | 84 | 142+No. 17 | 29 | 148 | 37 | 135 | 264 | 298 | 38 | 20 | 38 | — | — | 74 |
| 535 | 74 | 89 | 205 | 28 | 141 | 38 | 129 | 231 | 293 | 37 | 24 | 40 | 83 | 19.5 | 76 |
| 542 | 68 | 83 | 231 | 29 | 152 | 41 | 146 | 260 | 294 | 38 | 24 | 39 | 79 | 21 | 74 |
| 545 | 71 | 87 | 223 | 30 | 157 | 40 | 142 | — | 370 | 21 | 22 | 34 | 78 | 20.5 | 75 |
| 545 | 76 | 89 | 239 | 29 | 154 | 38 | 152 | 283 | 312 | 32 | 25 | 36 | 81 | 21 | 90 |
| 550 | 77 | 92 | 228 | 29 | 162 | 39 | 143 | 270 | 318 | 33 | 24 | 41 | 81 | 19 | 77 |
| 552 | 72 | 85 | 216 | 30 | 153+ | — | 148+ | 270 | — | 38 | 23 | 42 | 75 | 20 | 82 |
| 570 | 71 | 90 | 226 | 30 | 161 | 43 | 161 | 285 | 322 | 38 | 27 | 50 | 95 | 23 | 90 |
| 577 | 72 | 87 | — | 27.5 | — | 42 | — | — | — | — | — | — | — | — | 82 |
| 633 | 85 | 98 | 278 | 30 | 183 | 47 | 170 | 278 | 341 | — | 28 | 41 | 93 | 23 | 140 |
| 680 | 78 | 100 | 283+ | 36 | 189 | 55 | 190 | 357 | 382 | 47 | 34 | 53 | 114 | 24 | 106 |

## EXPLANATION OF PLATES

All figures are the fin whale foetuses from the Antarctic.

### PLATE I

A: Male, 25 cm long (No. 13T606)
B: Female, 45.5 cm long (No. 13T589)
C: Female, 50.5 cm long (No. 13T529)
D: Female, 83 cm long (No. 13T165)

### PLATE II

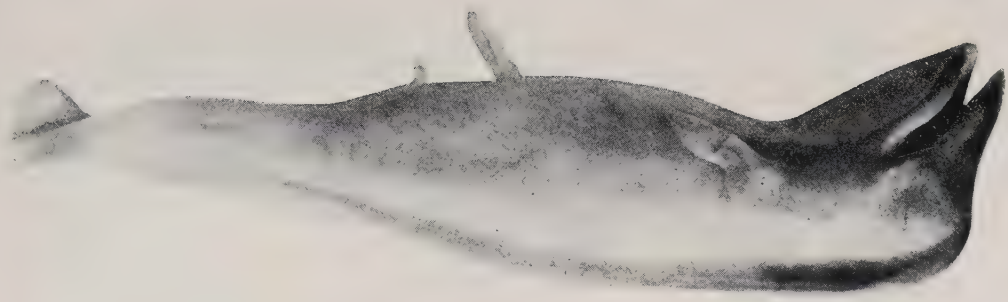
E: Male, 97 cm long (No. 13T67)
F: Male, 116 cm long (No. 13T124)
G: Female, 121 cm long (No. 13T156)
H: Female, 167 cm long (No. 13T40)

### PLATE III

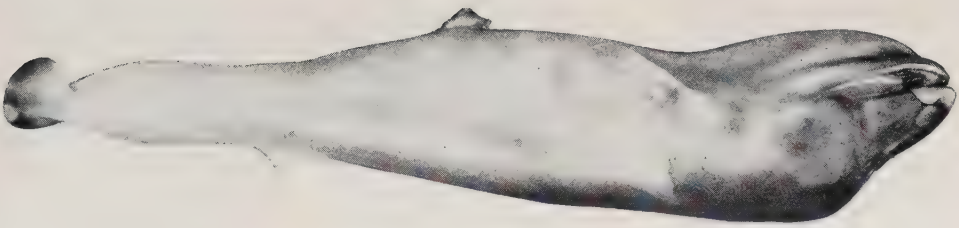
I: Male, 155 cm long (No. 13T585)
J: Male, 239 cm long (No. 13T160)
K: Female, 262 cm long (No. 13T101)

### PLATE IV

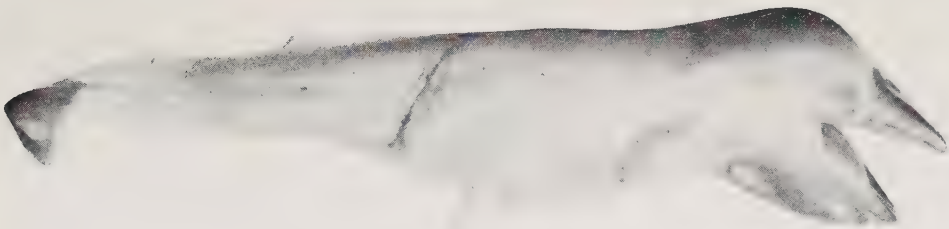
L: Female, 427 cm long (No. 13T1454)
M: Male, 485 cm long (No. 13T1400)



A



B



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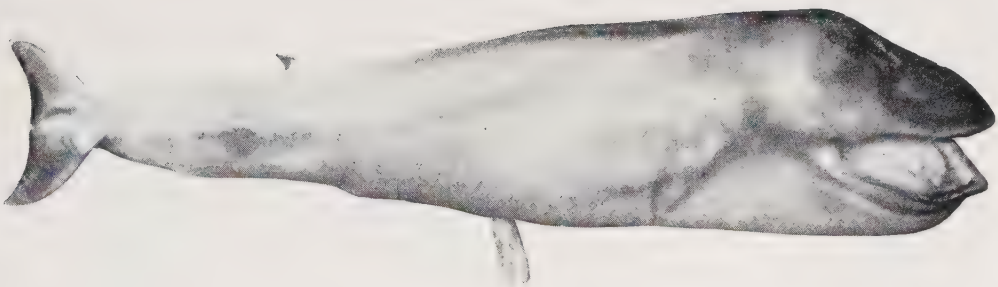

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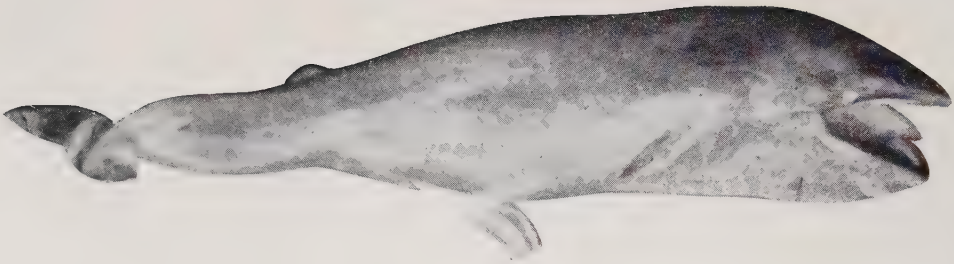

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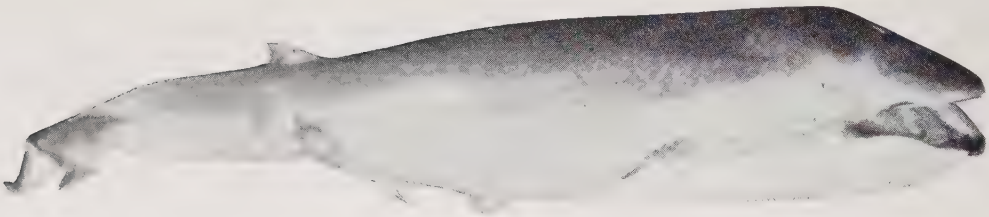

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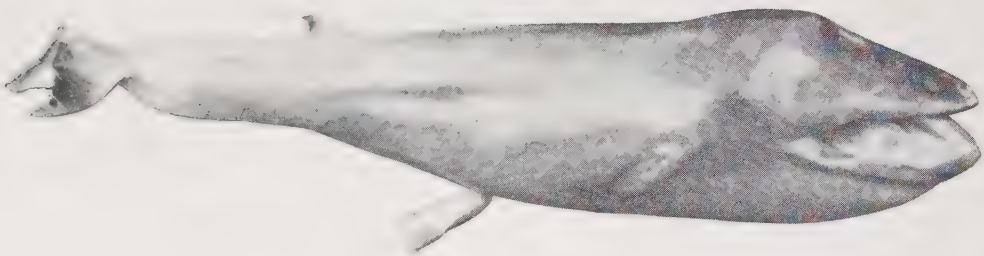

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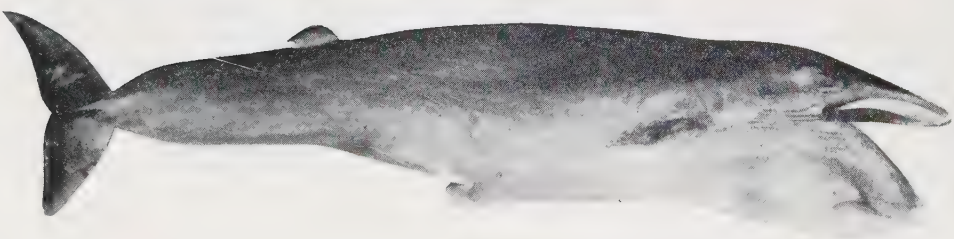
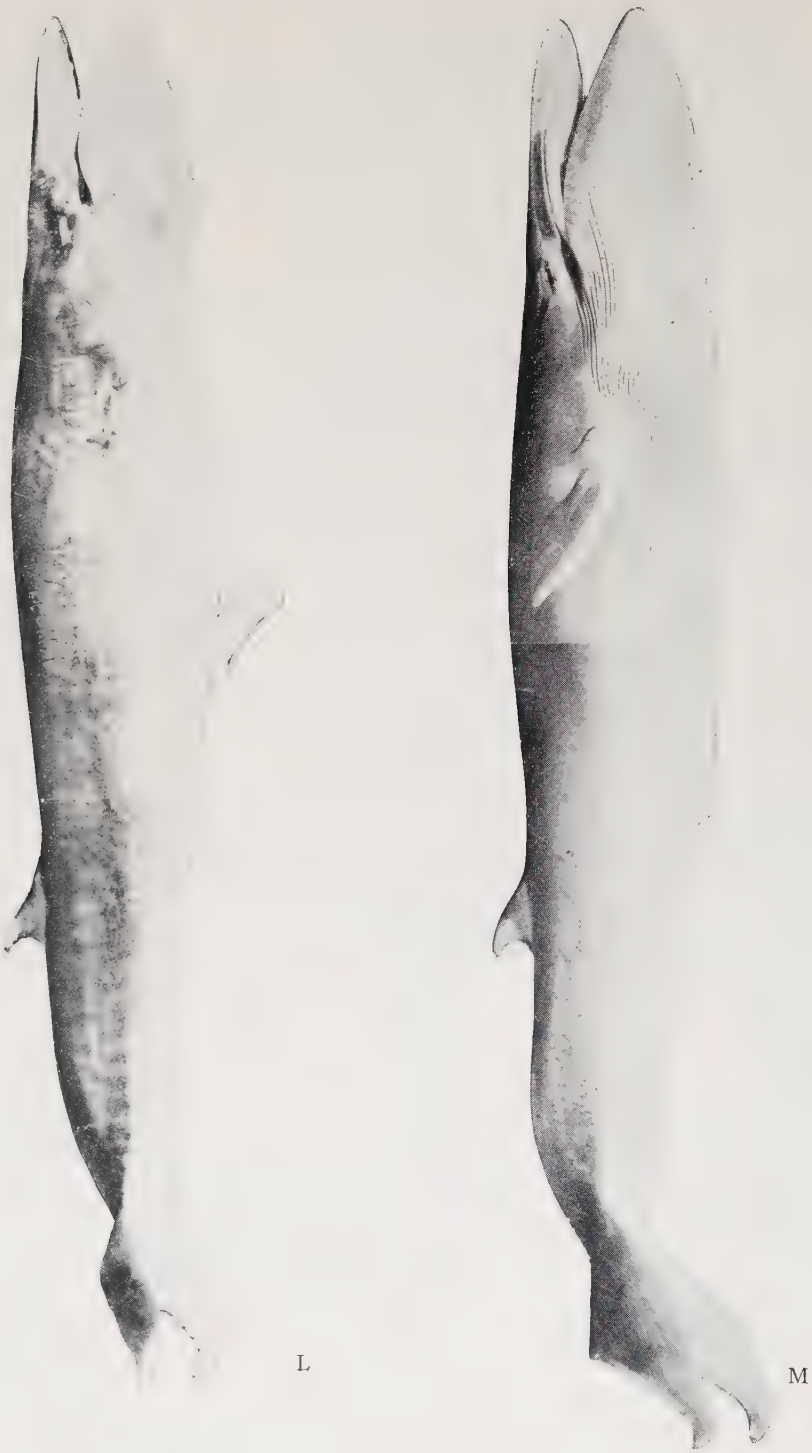


H

I J K



L M

# IMMUNOGENETIC AND MARKING APPROACHES TO IDENTIFYING SUBPOPULATIONS OF THE NORTH PACIFIC WHALES[1)]

KAZUO FUJINO

To identify local subpopulations of whales, various methods have been applied. These include indirect methods basing upon oceanographic information, seasonal change of localization of whaling grounds and catch statistics, parasitological analysis, and direct methods of morphological and marking investigations. Recently another method using ecological characters was adopted to analyse mingling of southern humpback populations (Chittleborough, 1959).

Morphological and marking investigations are most frequently utilized among these. Most morphological characteristics are controlled with polygenic system and are apt to be affected by non-hereditary factors during growth of individuals, so that discrimination of different populations may sometimes run into difficulties. On the other hand, marking investigation gives the most definite informations about movements of marked whales. To deduce, however, distribution of general population to which marked whales are belonged, effects of various conditions when marked or recaptured and of ecological factors should be discussed.

From these reasons, another method of population genetics might bring more useful informations. In this method, some characters which are controlled with comparatively simple allele system, such as blood groups in human (Boyd, 1950) (Race & Sanger, 1954), in cattle (Owen, Stormont & Irwin, 1947), in fowl (Brile *et al.*, 1958) and pigmentations in insect (Komai, Chino & Hoshino, 1956) are used as genetic marker.

Recently serological characters have been utilized as 'genetic marker' to identify intraspecific subpopulations of marine animals commercially valuable in fisheries. These include studies on tuna (Cushing, 1956; Suzuki *et al.*, 1959), salmon (Takahashi & Suyehiro, 1957; Ridgway, Cushing & Durall, 1958), Pacific sardine (Sprague, 1959), Atlantic herring (Sinderman, 1959), fur-seal (Fujino & Cushing, 1960) and whales (Fujino, 1956; Cushing, Fujino & Takahashi, 1959).

In the present paper serological basic studies on whales, carried out since 1952, are summarized and analysis of raciation of the North Pacific finback whales by means of population genetics with blood group and

[1)] Supported in part by the grants of the Japanese Fisheries Agency during from years 1955 to 1958. Outlines were read at International Oceanographic Congress, New York, Sept., 1959.

marking investigations are discussed with attention to complemental relationships between these two methods.

## BASIC PROBLEMS IN SEROLOGY

To identify whale populations by means of blood typing investigation, not only analysis of serological characteristics of themselves but also standardization of experimental methods and materials should be undertaken. Results of discussion on these technical problems are described in the following section. Other general methods used in successive sections are same as those in the literatures cited there.

*Technical problems, especially preserving methods of materials and blood typing with preserved materials*

a) Glycerol-freezing preservation technique of intact erythrocytes. Race and Sanger (1954) stated about studies on glycerol-freezing technique, 'There seems general agreement that antigens are well preserved at least up to a year and probably much longer. The method has been of great use in keeping available samples of blood representing rare genotypes'. Cushing *et al.* (1959) reported an application of this technique on marine animals of which sterile precautions are not available. After collecting blood samples are added equal volume of a mixture of four parts of glycerol and six parts of five percent sodium citrate solution (additional antimicrobial of guanofuracin was used at a concentration of 200 mg per liter against accidental warming), and then the mixture are kept frozen.

After transportation to laboratory, frozen samples are thawed under running water and are dialysed against 1.5 percent saline for two hours, and are washed several times with saline. Then the cells available for test will be obtained in good yield. All blood samples of finback and humpback whales, collected in 1958 and 1959, were analysed through this technique.

b) Blood typing of dried erythrocytes with $^{131}$I-labelled antibody. Fujino & Cushing (1959) developed another blood typing technique using dried erythrocytes and radioactive antibodies. Outlines of this technique are as follows. After being diluted one in ten with saline, one drop of fresh blood sample is dried on stripe of filter paper and is preserved in desiccator. Then $^{131}$I-labelled antibody is diffused on the filter paper with solvent of four per cent ammonium sulfate through the erythrocytes. Specific radioactivity on blood spot shows positive reaction between antibody and corresponding erythrocytes. According to their conclusive description, this technique will be useful in blood-typing of dried erythrocytes, but there are still general problems about preparation of

samples before applying to large scale of investigation.

c) Preservation of blood typing reagents. To undertake blood typing investigation of marine organisms in relation to fisheries problems, large number of sample should be tested for a long period. For this purpose it is desirable to use same standard reagents during a series of investigation. In past time many workers used formalin, merthiolate, carbolic acid and sodium azide as preservative of serum. While Race & Sanger (1954) stated that reagents for human blood typing can be preserved for long time by freezing at a temperature of −20°C without preservative. As blood typing of marine animals, however, is sometimes carried out in field laboratory, it is required to add preservative to serums against warming during transportation. In practical, after inactivation serum reagents are added 1/10 volume of five per cent of carbolic acid or one per cent of sodium-azide, and are kept frozen at temperature −15 or −20°C. Another series of reagents divided from original serums have been kept frozen at same temperature without preservative for use in central laboratory. No significant differences in specificities and titers has been recognized between both series of reagents even after three years' preservation so far.

*Classification and genetics of blood group*

Agglutination or hemolysis reaction with immune antibody, isohemagglutinin and natural antibody are used for detecting blood group antigens. Summarized results of blood typing on four species of baleen whales and three species of toothed whales detected so far are shown in Table 1. Details by species will be described in following paragraphs.

a) Blue-white dolphin, *Stenella caeruleo-albus*[1]. Two kinds of antigens are detected by agglutination and hemolysis reactions with rabbit immune serums, and isoagglutinins specific to these two antigens are found in low frequency (Yamaguchi & Fujino, 1953). Parenthesized figures in Table 2 show expected frequencies of occurrence of phenotypes calculated through hypothetical two allele system on population in Hardy-Weinberg's equilibrium.

It is not clear at present whether discrepancies between expected figures and observed those are caused by scantiness of samples tested or in compatibility of the allele system adopted.

Another kind of agglutinogen was detected in S. 23 dolphin cells, and occurred one out of ten individuals tested. No information on genetics on this antigen has not been obtained so far (Cushing, Fujino & Takahashi, 1959 ; Fujino & Cushing, 1959).

[1] More recently these common name and scientific name are used for this species which blood typing were reported by Yamaguchi and Fujino (1953).

TABLE 1. BLOOD GROUPS IN VARIOUS SPECIES OF WHALES

| Classification of whales | Whale species: Common name | Whale species: Scientific name | Blood groups: Phenotype | Blood groups: Detecting method of antigens | Literature |
|---|---|---|---|---|---|
| Toothed whale | Blue-white dolphin | *Stenella caeruleo-albus* | $Dc_1Dc_2$, $Dc_1$, $Dc_2$ | Agglutination and hemolysis reactions with immune antibodies | Yamaguchi & Fujino (1952) |
| | Baird-beaked whale | *Berardius bairdii* | $Br_1Br_2$, $Br_1$, $Br_2$; $Pb^+$, $Pb^-$ | | Fujino (1954) |
| | Sperm whale | *Physeter catodon* | $Pc_1Pc_2$, $Pc_1$, $Pc_2$; $Sp^+$, $Sp^-$ | | |
| Baleen whale | Bryde whale | *Balaenoptera edeni* | $Bb_1^+$, $Bb_1^-$ and $Bb_2^+$, $Bb_2^-$ | | |
| | Fin whale | *B. physalus* | $Bp_1^+$, $Bp_1^-$ and $Bp_2^+$, $Bp_2^-$ | Ditto and isoagglutination | Fujino (1953) |
| | | | $Ju_1Ju_2$, $Ju_1$, $Ju_2$ | Agglutination reaction with immune and natural antibodies | Fujino (1956) |
| | Blue whale | *B. musculus* | $Bm_1^+$, $Bm_1^-$ and $Bm_2^+$, $Bm_2^-$ | Agglutination and hemolysis with immune antibodies and isoagglutination | Fujino (1953) |
| | Humpback whale | *Megaptera nodosa* | $Mn_1^+$, $Mn_1^-$ and $Mn_2^+$, $Mn_2^-$ | | |
| | | | 1, 2, 3, 4 | Agglutination with anti-finback Ju immune and natural antibodies | Cushing, Fujino & Takahashi (1959) |

TABLE 2. FREQUENCY OF OCCURRENCE OF BLOOD TYPES OF BLUE-WHITE DOLPHIN

| Blood type | Male | Female | Sum |
|---|---|---|---|
| $Dc_1$ | .200 | .187 | .194 (.235) |
| $Dc_1Dc_2$ | .500 | .688 | .583 (.500) |
| $Dc_2$ | .300 | .125 | .223 (.265) |
| No. of whales observed | 20 | 16 | 36 |

b) Baired-beaked whale, *Berardius bairdii*. Three kinds of antigens $Br_1$, $Br_2$ and Pb are found by agglutination and hemolysis reactions with immune rabbit serums. According to phenotypic relationships Pb antigen seems to occur independently to $Br_1$ and $Br_2$ antigens. Frequencies of occurrence of phenotypes are shown in Table 3. Parentages of blood types are tested on two pairs of cow and fetus.

TABLE 3. FREQUENCY OF OCCURRENCE OF BLOOD TYPES OF BAIRD-BEAKED WHALE

| | Blood type | Male | Female | Sum |
|---|---|---|---|---|
| Br system | $Br_1$ | .820 | .750 | .804 |
| | $Br_1Br_2$ | .103 | .083 | .098 |
| | $Br_2$ | .077 | .167 | .098 |
| | No. of whales observed | 39 | 12 | 51 |
| Pb system | Pb present | .125 | .000 | .100 |
| | Pb absent | .875 | 1.000 | .900 |
| | No. of whales observed | 32 | 8 | 40 |

After being tested with agglutination-inhibition reaction, blood types both of male fetus 8 feet 3 inch. long taken from 37 feet cow and of female fetus 8 feet 7 inch. long taken from 36 feet cow were identified as $Br_1Pb^-$ which are same as those of their cow (Fujino, 1954).

Informations on isoagglutinin and allele system of three antigens have not been obtained yet.

c) Sperm whale, *Physeter catodon*. Three kinds of antigens of $Pc_1$, $Pc_2$ and Sp are found by agglutination and hemolysis reactions with

TABLE 4. FREQUENCY OF OCCURRENCE OF BLOOD TYPES OF SPERM WHALES

| | Blood type | Male | Female | Sum |
|---|---|---|---|---|
| Pc system | $Pc_1$ | .400 | .313 | .346 |
| | $Pc_1Pc_2$ | .300 | .313 | .308 |
| | $Pc_2$ | .300 | .374 | .346 |
| Sp system | Sp present | .400 | .500 | .462 |
| | Sp absent | .600 | .500 | .538 |
| No. of whales observed | | 10 | 16 | 26 |

immune rabbit and fowl serums. According to phenotypic relationships, antigen Sp belongs into different allele system from those which antigens $Pc_1$ and $Pc_2$ are concerned. Frequency of occurrence of phenotypes is shown in Table 4.

Natural antibody specific to Sp antigen is detected in the serums of sei whales, *Balaenoptera borealis* and agglutinates Sp positive cells up to dilution of one in eight or one in sixteen (Fujino, 1954). No available data about isoagglutinin specific to known antigens and allele system has been obtained yet.

d) Bryde whale (Ogasawara whale), *Balaenoptera edeni*[1]. Two kinds of blood group antigens $Bb_1$ and $Bb_2$ are detected by immune rabbit agglutinins and hemolysins in the Bryde whale taken from Bonin Islands' area, and occur as shown in Table 5 (Fujino, 1953). Sufficient data discussing on allele system of both antigens are not obtained yet. According to phenotypic relationships, however, antigens $Bb_1$ and $Bb_2$ seem to be controlled by different allele systems each other. No agglutinin, which has sufficient high titer and specificity to identify the known antigens, has been positively detected yet.

TABLE 5. FREQUENCY OF OCCURRENCE OF BLOOD TYPE ANTIGENS OF BRYDE WHALE[1]

| Present or absent of antigen | | Male | Female | Sum |
|---|---|---|---|---|
| $Bb_1$ antigen | $Bb_1$ present | .364 | .500 | .407 |
| | $Bb_1$ absent | .636 | .500 | .593 |
| $Bb_2$ antigen | $Bb_2$ present | .273 | .300 | .281 |
| | $Bb_2$ absent | .727 | .700 | .719 |
| No. of whales observed | | 22 | 10 | 32 |

e) Finback whale, *Balaenoptera physalus*. At first two kinds of antigens $Bp_1$ and $Bp_2$ were found by immune rabbit agglutinins and hemolysins (Fujino, 1953). According to phenotypic relationships these two antigens seem to be controlled by different allele system each other. Additional two antigens belong to Ju system were detected independently to the known two antigens by immune rabbit and fowl agglutinins. In consequence twelve phenotypes can be possible as shown in Table 6.

TABLE 6. TWELVE PHENOTYPES OF FINBACK BLOOD GROUPS CLASSIFIED WITH Bp AND Ju ANTIGENS*

| Bp antigen | Ju antigen | | | | | |
|---|---|---|---|---|---|---|
| | $Ju_1$ | | $Ju_1Ju_2$ | | $Ju_2$ | |
| $Bp_1$ and $Bp_2$ present | $Bp_1Bp_2$ | $Ju_1$ | $Bp_1Bp_2$ | $Ju_1Ju_2$ | $Bp_1Bp_2$ | $Ju_2$ |
| $Bp_1$ present | $Bp_1$ | $Ju_1$ | $Bp_1$ | $Ju_1Ju_2$ | $Bp_1$ | $Ju_2$ |
| $Bp_2$ present | $Bp_2$ | $Ju_1$ | $Bp_2$ | $Ju_1Ju_2$ | $Bp_2$ | $Ju_2$ |
| $Bp_1$ and $Bp_2$ absent | O | $Ju_1$ | O | $Ju_1Ju_2$ | O | $Ju_2$ |

* cited from Fujino (1956)

[1] Sei whales taken from Bonin Islands' area (Fujino, 1953) are identified as different species from *Balaenoptera borealis* (Omura, Nishimoto & Fujino, 1952). More recently, these common name and scientific name are adopted to this species by Omura *et al.* (1957) and Omura (1959).

Another new antigen X were detected positively in $Bp_2Ju_1$ and $OJu_1$ type cells, but relations to the known antigens have not been studied enough yet (Fujino, 1956).

Cushing *et al* (1959) stated that homozygous and heterozygous types, which belong to Ju system, reveal dosage effects against anti-$Ju_2$ antibody. This was confirmed with additonal experiments using materials

TABLE 7. DOSAGE EFFECT IN HETEROZYGOUS TYPE OF FINBACK Ju BLOOD GROUP

Anti-$Ju_2$ no. 50 immune rabbit serum (absorbed)

| Cells | | Dilution | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20 | 40 | 80 | 160 | 320 | 640 | 1280 | 2560 | 5120 | 10240 |
| $Ju_1$ | 503 | — | — | — | — | — | — | — | — | — | — |
| $Ju_1Ju_2$ | 181 | ## | ## | ## | ## | ## | # | # | + | — | — |
| | 455 | ## | # | # | + | — | — | — | — | — | — |
| $Ju_2$ | 504 | ## | ## | ## | ## | ## | ## | ## | ## | + | + |

Anti-$Ju_2$ no. 34 immune rabbit serum (absorbed)

| Cells | | Dilution | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 40 | 80 | 160 | 320 | 640 | 1280 |
| $Ju_1$ | 503 | — | — | — | — | — | — | — | — |
| $Ju_1Ju_2$ | 181 | ## | ## | ## | ## | ## | # | + | — |
| | 455 | ## | ## | ## | # | + | + | — | — |
| $Ju_2$ | 504 | ## | ## | ## | ## | ## | ## | # | + |

No. 2 horse serum (unabsorbed)

| Cells | | Dilution | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 4 | 8 | 16 | 32 | 64 | 128 | 256 | 512 |
| $Ju_1$ | 503 | + | — | — | — | — | — | — | — | — | — |
| $Ju_1Ju_2$ | 181 | + | # | ## | ## | ## | ## | # | + | — | — |
| | 455 | ## | ## | ## | ## | # | + | — | — | — | — |
| $Ju_2$ | 504 | + | # | ## | ## | ## | ## | ## | # | # | + |

Anti-$Ju_1$ no. 47 immune fowl serum (absorbed)

| Cells | | Dilution | | | |
|---|---|---|---|---|---|
| | | 10 | 20 | 40 | 80 |
| $Ju_1$ | 503 | ## | ## | # | + |
| $Ju_1Ju_2$ | 181 | ## | ## | # | + |
| | 455 | ## | ## | # | + |
| $Ju_2$ | 504 | — | — | — | — |

which were collected by glycerol-freezing technique in 1959. Conversely, this phenomena may serve to distinguish heterozygous type from homozygous type.

Moreover another two types which revealed dosage effect against anti-$Ju_2$ serum were found among Ju heterozygous types ($Ju_1Ju_2$) as shown in Table 7. In this table results of reaction against anti-$Ju_1$

serum show that there is no difference in antigenic activity between nos. 455 and 181 heterozygous erythrocytes after preservation. Large number of investigation about this point has not been carried out, but the results of Table 7 show that heterozygous type ($Ju_1Ju_2$) may be subdivided into two groups, that is, stronger one and weaker one.

As shown in Table 8 natural antibodies specific to Ju antigen are detected positively in the serums of fowl, rabbit, pig, horse and cattle. As already reported in part by Cushing *et al.* (1959) no difference has been recognized on anti-$Ju_2$ specificity between immune and natural antibodies so far. Additional advantage, which these natural antibody occur in high frequency, will be potentially useful in large scale of blood typing investigations hereafter.

TABLE 8. ANTI-FINBACK Ju NATURAL ANTIBODIES FROM SERUMS OF VARIOUS SPECIES OF ANIMALS[1)]

| Animal | Specificity of antibody | Agglutinin titer[2)] | Frequency of occurrence | Remark |
|---|---|---|---|---|
| Fowl | anti-$Ju_1$ | 1:2 | one out of three | detected from a same individual |
| | anti-$Ju_2$ | 1:4 | ditto | |
| Rabbit | anti-$Ju_2$ | 1:8~1:64 | three out of five | |
| Pig | anti-$Ju_2$ | 1:256 | only one tested | |
| Horse | anti-$Ju_2$ | 1:64~1:2560 | all of eleven | Five out of eleven possess finback species specific antibody in common. |
| Cattle | anti-$Ju_2$ | 1:32~1:40960 | all of thirteen | |

1) partly reported already by Fujino (1958) and Cushing, Fujino & Takahashi (1959).
2) agglutinin titer against homozygous type $Ju_2$ in room temperature.

TABLE 9. BLOOD TYPE ANTIGENS OF FINBACK WHALES USED FOR LARGE SCALE OF INVESTIGATIONS IN VARIOUS AREAS

| Year | East China Sea | Kamchatka off | South of east Aleutian | North of east Aleutian | Off Navarin and Olyutorskiy |
|---|---|---|---|---|---|
| 1952 | | Bp | | | |
| 54 | | Bp and Ju | | Bp and Ju | |
| 55 | | Bp and Ju | Bp and Ju | Bp and Ju | |
| 56 | Ju | | | | |
| 57 | Ju | | | | |
| 58 | | Ju | Ju | Ju | Ju |
| 59 | | Ju | Ju | Ju | |

While Fujino (1958) stated that immune animal which has natural antibody specific to Ju antigen can produce more excellent antibody in specificity and titer against corresponding Ju antigen than other animals. Basing upon the above stated knowledges have been undertaken large number of blood typing of finback whales from various areas of the north Pacific.

Fujino (1956) stated that in large scale of investigation blood typing

TABLE 10. FREQUENCY OF OCCURRENCE OF Bp AND Ju BLOOD GROUP ANTIGENS OF FINBACK WHALES[1]

| Bp antigen | | Off Kamchatka[2] | | | | | | South of E. Aleut. | | | North of E. Aleut. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1952 | | | 1954 & 55 | | | | | | | | |
| | | male | female | sum | male | female | sum | male | female | sum | male | female | sum |
| $Bp_1$ | present | .310 | .260 | .285 | .151 | .148 | .149 | .000 | .000 | .000 | .000 | .000 | .000 |
| | absent | .690 | .740 | .715 | .849 | .852 | .851 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| $Bp_2$ | present | .190 | .270 | .230 | .250 | .264 | .256 | .526 | .462 | .500 | .218 | .221 | .219 |
| | absent | .810 | .730 | .770 | .750 | .736 | .744 | .474 | .538 | .500 | .782 | .779 | .781 |
| No. of whales tested | | 100 | 100 | 200 | 232 | 197 | 429 | 19 | 13 | 32 | 726 | 701 | 1427 |

| Ju blood group | East China Sea | | | Off Kamchatka | | | South of E. Aleut. | | | North of E. Aleut. | | | Navarin | | | Olyutorskiy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | male | female | sum | male | female | sum | male | female | sum | male | female | sum | male | female | sum | male | female | sum |
| $Ju_1$ | .692 | .781 | .736 | .833 | .857 | .844 | .950 | .919 | .937 | .981 | .984 | .982 | .952 | .914 | .934 | 1.000 | 1.000 | 1.000 |
| $Ju_1Ju_2$ | .108 | .094 | .101 | .048 | .034 | .042 | .025 | .030 | .027 | .007 | .005 | .006 | .024 | .029 | .026 | .000 | .000 | .000 |
| $Ju_2$ | .200 | .125 | .163 | .119 | .109 | .114 | .025 | .051 | .036 | .012 | .011 | .012 | .024 | .057 | .040 | .000 | .000 | .000 |
| No. of whales tested | 65 | 64 | 129 | 438 | 348 | 786 | 121 | 99 | 220 | 810 | 821 | 1631 | 41 | 35 | 76 | 8 | 5 | 13 |

1) Include data of Fujino (1953), Fujino (1956), Cushing, Fujino & Takahashi (1959) and additional those in 1959.
2) Figures in 1952 and 1954 & 1955 are noted separately here, because same reagents were not used in these years.

in Ju system can give higher precision than in $Bp_1$ and $Bp_2$ antigens because of some misclassification resulting from unknown antigen-antibody reactions involved. Therefore, Ju system alone is used for practical investigation ever since. Blood groups, which were adopted for investigations in various areas in each year, are shown in Table 9. Table 10 shows their frequency of occurrence obtained. In this table the results in 1952 are described separately from those in 1954 and 1955, because in 1952 no discussion was performed on the effect of X antigen which was found subsequently. It is clear from this table that $Bp_1$ antigen which occurs in the area off Kamchatka does not occur in the area of east Aleutian and that frequencies of $Ju_2$ antigen show geographical gradient descending from western to eastern sides of the north Pacific. Problems on identification and mingling of intraspecific subpopulations will be discussed later.

TABLE 11. SIZE DISTRIBUTION OF FIN WHALE FETUSES OF WHICH BLOOD GROUPS WERE IDENTIFIED

| Body length in feet | Male | | | Female | | |
|---|---|---|---|---|---|---|
| | $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ | $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ |
| 4 | 1 | | 1 | | 1 | |
| 5 | | | | 3 | | |
| 6 | 4 | 1 | | 6 | | |
| 7 | 7 | 1 | | 2 | | 1 |
| 8 | 6 | 1 | | 7 | | 1 |
| 9 | 3 | | | 2 | | |
| 10 | 3 | | | | 1 | |
| 11 | 2 | 1 | | 3 | | |
| 12 | 3 | | | 2 | | |
| 13 | 2 | 2 | | 1 | | |
| 14 | 1 | | | 1 | | |
| Sum | 32 | 6 | 1 | 27 | 2 | 2 |

Parentages of blood types between cows and their fetuses taken and population genetics using relative frequencies of occurrence of each phenotype were used for finding allele system of blood types. Blood samples taken from umbilical cords of fetuses were used for analysis. Embryological problems of blood types in fetal stages were taken into consideration. After discussing developments of human blood types in fetuses by means of agglutination and agglutination-inhibition reactions, Mizu (1931) and Hirasawa (1935) stated that phenotypes in ABO and MN systems can be already identified approximately three months after fertilization. Therefore, data on whale fetuses, of which blood types were definitely identified with above stated two reactions alone are used for discussion of parentages of blood types in whales.

Table 11 shows body length distribution of fetuses of which blood

tpyes were able to be identified. Judging from averaged growth curve estimated by Nozawa *et al* (Nozawa *et al*. 1956, pp. 44–55) and Ohsumi *et al*. (1958) it may be assumed that fetal blood types of the north Pacific finbacks can be identified already five or six months after fertilization. The parentages of blood types observed are shown in Table 12. According to this table Ju blood type seems to be hereditarily controlled by two allele system, but one exception of parentage has been observed. That is, $Ju_1$ type fetus was taken from $Ju_2$ type cow[1]. This does not fit hypothesis in two allele system. Therefore, further discussions will be taken up by means of population genetics using relative frequency of occurrence of phenotypes as follows.

TABLE 12. PARENTAGES OF Ju BLOOD GROUPS OF FINBACKS[1]

| Mother whale | | Blood groups of fetus | | |
|---|---|---|---|---|
| blood group | no. of tested | $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ |
| $Ju_1$ | 56 | 53 | 3 | 0 |
| $Ju_1Ju_2$ | 7 | 5 | 1 | 1 |
| $Ju_2$ | 7 | 1 | 4 | 2 |
| Sum | 70 | 59 | 8 | 3 |

[1] Results in the years 1954, 55 & 59.

Phenotypic relationships of Ju blood types noted in Table 6 are discussed as follows from view points of presence or absence of antigens.

i) Erythrocytes lacking $Ju_1$ antigen are certain to have $Ju_2$ antigen, and erythrocytes lacking $Ju_2$ antigen are certain to have $Ju_1$ antigen. That is, no erythrocytes which has neither antigen $Ju_1$ nor $Ju_2$ has been observed.

ii) Erythrocytes possessing both antigens $Ju_1$ and $Ju_2$ exists.

Probable hypothetical two allele and three allele systems were discussed by means of population genetics. At first relations of dominancy among alleles were defined as follows. Parenthesized symbols mean frequency of occurrence of each gene. In two allele system, there is no relation of dominancy between $j_1$ ($p$) and $j_2$ ($q$) genes. In three allele A system, $j_1^d$ ($q$) gene is completely dominant against $j_2$ ($r$) gene and no relation of dominancy exist between $j_2$ and $j_1$ ($p$) genes. In three allele B system, $j_2^r$ ($r$) gene is completely ressesive against $j_1$ ($p$) gene and $j_2$ ($q$) gene is equivalent to $j_1$ gene. Then genotype-phenotype relations are given in Table 13. In two allele system one phenotype corresponds to each one genotype. In three allele A system $Ju_1$ phenotype includes four genotypes and other two phenotypes have one genotype each. In three allele B system phenotypes $Ju_1$, $Ju_1Ju_2$ and $Ju_2$ include two, one and three genotypes respectively.

[1] According to the log supervised by Mr. K. Nasu, Whales Research Institute, these are no. 1542 cow 70 feet long and male fetus 8 feet and 6 inch. long taken in the area of the north of east Aleutian (54°27′N, 168°32′W) in Aug. 4, 1959.

TABLE 13. PHENOTYPE-GENOTYPE RELATIONSHIPS IN THREE KINDS OF ALLELE SYSTEMS

| Phenotype | Genotype | | |
|---|---|---|---|
| | two allele system | three allele A system | three allele B system |
| $Ju_1$ | $j_1j_1$ | $j_1j_1$, $j_1j_1^a$, $j_1^aj_1^a$, $j_1^aj_2$ | $j_1j_1$, $j_1j_2^r$ |
| $Ju_1Ju_2$ | $j_1j_2$ | $j_1j_2$ | $j_1j_2$ |
| $Ju_2$ | $j_2j_2$ | $j_2j_2$ | $j_2j_2$, $j_2j_2^r$, $j_2^rj_2^r$ |

In a population at Hardy-Weinbergs' equilibrium, following relations between frequencies of occurrence of phenotypes and those of genotypes can be formulated. That is, in two allele system,

$$\left.\begin{aligned}[Ju_1]&=p^2\\ [Ju_1Ju_2]&=2pq\\ [Ju_2]&=q^2\\ p+q&=1\end{aligned}\right\} \quad (1)$$

, in three allele A system

$$\left.\begin{aligned}[Ju_1]&=(p+q)^2+2qr\\ [Ju_1Ju_2]&=2pr\\ [Ju_2]&=r^2\\ p+q+r&=1\end{aligned}\right\} \quad (2)$$

, and in three allele B system

$$\left.\begin{aligned}[Ju_1]&=p^2+2pr\\ [Ju_1Ju_2]&=2pq\\ [Ju_2]&=(1-p)^2\\ p+q+r&=1\end{aligned}\right\} \quad (3)$$

, where $[Ju_1]$, $[Ju_1Ju_2]$ and $[Ju_2]$ mean frequency of occurrence of each phenotype and a relation of $[Ju_1]+[Ju_1Ju_2]+[Ju_2]=1$ is provided.

TABLE 14. FREQUENCY OF OCCURRENCE OF PHENOTYPES AND GENES OF Ju BLOOD GROUPS OF FINBACK WHALES

| Freq. of occurrence of phenotypes and genes | | East China Sea | | Kamchatka (A) | | South of east Aleutian (B) | | North of east Aleutian (C) | |
|---|---|---|---|---|---|---|---|---|---|
| | | act. no. | freq. | act. no. | freq. | act. no. | freq. | act. no. | freq. |
| Observed | $[Ju_1]$ | 95 | .731 | 663 | .844 | 206 | .937 | 1602 | .982 |
| | $[Ju_1Ju_2]$ | 13 | .101 | 33 | .042 | 6 | .027 | 10 | .006 |
| | $[Ju_2]$ | 21 | .163 | 90 | .114 | 8 | .036 | 19 | .012 |
| | sum | 129 | | 786 | | 220 | | 1631 | |
| Two-allele system, exp. value | $p$ | .787 | | .865 | | .951 | | .985 | |
| | $q$ | .213 | | .135 | | .049 | | .015 | |
| | $[Ju_1]$ | 80 | .620 | 588 | .748 | 199.1 | .905 | 1582.4 | .9702 |
| | $[Ju_1Ju_2]$ | 43 | .335 | 184 | .234 | 20.5 | .093 | 48.3 | .0296 |
| | $[Ju_2]$ | 6 | .045 | 14 | .018 | 0.4 | .002 | 0.3 | .0002 |
| Three-allele system* A | $p$ | .125 | | .062 | | .071 | | .027 | |
| | $q$ | .471 | | .600 | | .739 | | .863 | |
| | $r$ | .404 | | .338 | | .190 | | .110 | |
| Three-allele system* B | $p$ | .596 | | .662 | | .810 | | .890 | |
| | $q$ | .085 | | .032 | | .017 | | .003 | |
| | $r$ | .319 | | .306 | | .173 | | .107 | |

* Calculated for convenience of comparison under a hypothesis which population in each area is in Hardy-Weinberg's equilibrium.

TABLE 15. EXPECTED FREQUENCY OF OCCURRENCE OF BLOOD TYPES OF CALVES FROM VARIOUS MATINGS IN HYPOTHETICAL THREE ALLELE SYSTEMS

1) In A system

| Mating phenotype | | Mating genotype | | Expected blood type of calves: genotype $j_1j_1$ | $j_1j_1^a$ | $j_1^aj_1^a$ | $j_1^aj_2$ | $j_1j_2$ | $j_2j_2$ | phenotype $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $[Ju_1]$ | $\times[Ju_1]$ | $j_1j_1$ | $\times j_1j_1$ | $p^4$ | | | | | | $p^4$ | | |
| | | | $\times j_1j_1^a$ | $p^3q$ | $p^3q$ | | | | | $2p^3q$ | | |
| | | | $\times j_1^aj_1^a$ | | $p^2q^2$ | | | | | $p^2q^2$ | | |
| | | | $\times j_1^aj_2$ | | $p^2qr$ | | | $p^2qr$ | | $p^2qr$ | $p^2qr$ | |
| | | $j_1j_1^a$ | $\times j_1j_1^a$ | $p^2q^2$ | $2p^2q^2$ | $p^2q^2$ | | | | $4p^2q^2$ | | |
| | | | $\times j_1^aj_1^a$ | | $pq^3$ | $pq^3$ | | | | $2pq^3$ | | |
| | | | $\times j_1^aj_2$ | | $pq^2r$ | $pq^2r$ | $pq^2r$ | $pq^2r$ | | $3pq^2r$ | $pq^2r$ | |
| | | $j_1^aj_1^a$ | $\times j_1^aj_1^a$ | | | $q^4$ | | | | $q^4$ | | |
| | | | $\times j_1^aj_2$ | | | $q^3r$ | $q^3r$ | | | $2q^3r$ | | |
| | | $j_1^aj_2$ | $\times j_1^aj_2$ | | | $q^2r^2$ | $2q^2r^2$ | | $q^2r^2$ | $3q^2r^2$ | | $q^2r^2$ |
| $[Ju_1]$ | $\times[Ju_1Ju_2]$ | $j_1j_1$ | $\times j_1j_2$ | $p^3r$ | | | | $p^3r$ | | $p^3r$ | $p^3r$ | |
| | | $j_1j_1^a$ | $\times j_1j_1$ | $p^2qr$ | $p^2qr$ | | $p^2qr$ | $p^2qr$ | | $3p^2qr$ | $p^2qr$ | |
| | | $j_1^aj_1^a$ | $\times j_1j_2$ | | $pq^2r$ | | $pq^2r$ | | | $2pq^2r$ | | |
| | | $j_1^aj_2$ | $\times j_1j_2$ | | $pqr^2$ | | $pqr^2$ | $pqr^2$ | $pqr^2$ | $2pqr^2$ | $pqr^2$ | $pqr^2$ |
| $[Ju_1]$ | $\times[Ju_2]$ | $j_1j_1$ | $\times j_2j_2$ | | | | | $p^2q^2$ | | | $p^2q^2$ | |
| | | $j_1j_1^a$ | $\times j_2j_2$ | | | | $pqr^2$ | $pqr^2$ | | $pqr^2$ | $pqr^2$ | |
| | | $j_1^aj_1^a$ | $\times j_2j_2$ | | | | $q^2r^2$ | | | $q^2r^2$ | | |
| | | $j_1^aj_2$ | $\times j_2j_2$ | | | | $qr^3$ | | $qr^3$ | $qr^3$ | | $qr^3$ |
| $[Ju_1Ju_2]$ | $\times[Ju_1Ju_2]$ | $j_1j_2$ | $\times j_1j_2$ | $p^2r^2$ | | | | $2p^2r^2$ | $p^2r^2$ | $p^2r^2$ | $2p^2r^2$ | $p^2r^2$ |
| $[Ju_1Ju_2]$ | $\times[Ju_2]$ | $j_1j_2$ | $\times j_2j_2$ | | | | | $pr^3$ | $pr^3$ | | $pr^3$ | $pr^3$ |
| $[Ju_2]$ | $\times[Ju_2]$ | $j_2j_2$ | $\times j_2j_2$ | | | | | | $r^4$ | | | $r^4$ |

2) In B system

| Mating phenotype | | Mating genotype | | Expected blood type of calves: genotype $j_1j_1$ | $j_1j_2^r$ | $j_1j_2$ | $j_2j_2$ | $j_2j_2^r$ | $j_2^rj_2^r$ | phenotype $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $[Ju_1]$ | $\times[Ju_1]$ | $j_1j_1$ | $\times j_1j_1$ | $p^4$ | | | | | | $p^4$ | | |
| | | | $\times j_1j_2^r$ | $p^3r$ | $p^3r$ | | | | | $2p^3r$ | | |
| | | $j_1j_2^r$ | $\times j_1j_2^r$ | $p^2r^2$ | $2p^2r^2$ | | | $p^2r^2$ | | $3p^2r^2$ | | $p^2r^2$ |
| $[Ju_1]$ | $\times[Ju_1Ju_2]$ | $j_1j_1$ | $\times j_1j_2$ | $p^3r$ | | $p^3r$ | | | | $p^3r$ | $p^3r$ | |
| | | $j_1j_2^r$ | $\times j_1j_2$ | $p^2qr$ | $p^2qr$ | $p^2qr$ | | $p^2qr$ | | $2p^2qr$ | $p^2qr$ | $p^2qr$ |
| $[Ju_1]$ | $\times[Ju_2]$ | $j_1j_1$ | $\times j_2j_2$ | | | $p^2q^2$ | | | | | $p^2q^2$ | |
| | | | $\times j_2j_2^r$ | | $p^2qr$ | $p^2qr$ | | | | $p^2qr$ | $p^2qr$ | |
| | | | $\times j_2^rj_2^r$ | | $p^2q^2$ | | | | | $p^2q^2$ | | |
| | | $j_1j_2^r$ | $\times j_2j_2$ | | | $pq^2r$ | | $pq^2r$ | | | $pq^2r$ | $pq^2r$ |
| | | | $\times j_2j_2^r$ | | $pqr^2$ | $pqr^2$ | | $pqr^2$ | $pqr^2$ | $pqr^2$ | $pqr^2$ | $2pqr^2$ |
| | | | $\times j_2^rj_2^r$ | | $pr^3$ | | | | $pr^3$ | $pr^3$ | | $pr^3$ |
| $[Ju_1Ju_2]$ | $\times[Ju_1Ju_2]$ | $j_1j_2$ | $\times j_1j_2$ | $p^2q^2$ | | $2p^2q^2$ | $p^2q^2$ | | | $p^2q^2$ | $2p^2q^2$ | $p^2q^2$ |
| $[Ju_1Ju_2]$ | $\times[Ju_2]$ | $j_1j_2$ | $\times j_2j_2$ | | | $pq^3$ | $pq^3$ | | | | $pq^3$ | $pq^3$ |
| | | | $\times j_2j_2^r$ | | $pq^2r$ | $pq^2r$ | $pq^2r$ | $pq^2r$ | | $pq^2r$ | $pq^2r$ | $2pq^2r$ |
| | | | $\times j_2^rj_2^r$ | | $pqr^2$ | | | $pqr^2$ | | $pqr^2$ | | $pqr^2$ |
| $[Ju_2]$ | $\times[Ju_2]$ | $j_2j_2$ | $\times j_2j_2$ | | | | $q^4$ | | | | | $q^4$ |
| | | | $\times j_2j_2^r$ | | | | $q^3r$ | $q^3r$ | | | | $2q^3r$ |
| | | | $\times j_2^rj_2^r$ | | | | | $q^2r^2$ | | | | $q^2r^2$ |
| | | $j_2j_2^r$ | $\times j_2j_2^r$ | | | | $q^2r^2$ | $2q^2r^2$ | $q^2r^2$ | | | $4q^2r^2$ |
| | | | $\times j_2^rj_2^r$ | | | | | $qr^3$ | $qr^3$ | | | $2qr^3$ |
| | | $j_2^rj_2^r$ | $\times j_2^rj_2^r$ | | | | | | $r^4$ | | | $r^4$ |

Table 14 shows gene frequencies calculated from Table 10 through these formulas. Results of statistical tests shows that Ju blood type does not fit hypothetical two allele system. This confirm incompatibility of two allele system which was previously noted in parentages. Therefore, analysis of raciation and mingling of different populations will be discussed through three allele A and B systems.

Frequency of expected blood groups in fetuses from various matings can be noted in Table 15 through two ways of A and B systems.

Dosage effect in heterozygous types noted in Table 7 would propose existence of subtypes to which an additional gene will concern. However, informations sufficient to statistical treatment have not been obtained yet.

f) Blue whale, *Balaenoptera musculus*. Two kinds of antigens $Bm_1$ and $Bm_2$ are found in the erythrocytes of north Pacific blue whale with rabbit immune agglutinins and hemolysins. Frequencies of occurrence of antigens are shown in Table 16. Isoagglutinins specific to known

TABLE 16. FREQUENCY OF OCCURRENCE OF BLOOD TYPE ANTIGENS OF BLUE WHALES

| Presence or absence of antigen | | Male | Female | Sum |
|---|---|---|---|---|
| $Bm_1$ antigen | $Bm_1$ present | .033 | .059 | .043 |
| | $Bm_1$ absent | .267 | .411 | .319 |
| $Bm_2$ antigen | $Bm_2$ present | .133 | .059 | .106 |
| | $Bm_2$ absent | .567 | .471 | .532 |
| No. of whales observed | | 30 | 17 | 47 |

antigens occur irregularly. Titers of anti-$Bm_1$ reach up to 1 : 4 or 1 : 64 and those of anti-$Bm_2$ up to 1 : 2 or 1 : 64 (Fujino, 1953). According to phenotypic relationships, antigens $Bm_1$ and $Bm_2$ seem to be controlled by genes belong to different allele systems each other, though informations enough to discuss has not been obtained.

g) Humpback whale, *Megaptera nodosa*. Two kinds of blood group antigens $Mn_1$ and $Mn_2$ are found in the north Pacific humpback whales

TABLE 17. FREQUENCY OF OCCURRENCE OF BLOOD TYPE ANTIGENS OF HUMPBACK WHALES

| Presence or absence of antigen | | Male | Female | Sum |
|---|---|---|---|---|
| $Mn_1$ antigen | $Mn_1$ present | .111 | .118 | .114 |
| | $Mn_1$ absent | .278 | .235 | .257 |
| $Mn_2$ antigen | $Mn_2$ present | .056 | .118 | .086 |
| | $Mn_2$ absent | .555 | .529 | .543 |
| No. of whales observed | | 18 | 17 | 35 |

with immune rabbit agglutinins and hemolysins. Frequency of occurrence of each antigen is shown in Table 17. Isoagglutinins specific to known antigens were detected positively at high frequency. Out of ten

samples tested, three have anti-$Mn_1$, three have anti-$Mn_2$, two have both and two have none of agglutinins. Titers of anti-$Mn_1$ and anti-$Mn_2$ agglutinins reach up to 1 : 2 or 1 : 128 and 1 : 4 or 1 : 128 respectively. Table 18 shows results of isoagglutination (Fujino, 1953).

TABLE 18. ISOHEMAGGLUTINATION IN Mn BLOOD TYPE ANTIGENS OF HUMPBACK WHALES

| Serums | Erythrocytes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 142 | 143 | 151 | 180 | 184 | 191 | 192 | 203 | 204 | 206 |
| 142 | — | — | — | — | — | — | — | ## | — | — |
| 143 | — | — | ## | — | — | — | — | ## | — | — |
| 151 | — | — | — | — | — | — | — | ## | — | — |
| 180 | — | — | ## | — | — | — | — | ## | — | — |
| 184 | — | — | + | — | — | — | — | — | — | — |
| 191 | — | — | ## | — | — | — | — | ### | — | — |
| 192 | — | — | ## | — | — | — | — | ### | — | — |
| 203 | — | — | — | — | — | — | — | — | — | — |
| 204 | — | — | ## | — | — | — | — | ### | — | — |
| 206 | — | — | — | — | — | — | — | ### | — | — |

Additional four kinds of blood types were temporarily classified on humpbacks taken from Okinawa waters with anti-finback Ju agglutinins (immune rabbit and fowl serums and natural antibodies from cattle and

TABLE 19. NEW BLOOD TYPES OF HUMPBACK WHALES TEMPORARILY CLASSIFIED BY ABSORBING TESTS OF ANTI-FINBACK Ju SERUMS

| Blood types of absorbing erythrocytes | Blood types of erythrocytes used as agglutinogen | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | — | — | — | — |
| 2 | + | — | — | — |
| 3 | + | + | — | — |
| 4 | + | + | + | — |

TABLE 20. ISOHEMAGGLUTINATION IN HUMPBACK WHALE BLOOD TYPES CLASSIFIED BY ANTI-FINBACK Ju SPECIFICITIES

| Serums | Blood types of erythrocytes | | | | | |
|---|---|---|---|---|---|---|
| | 1<br>K 9 | 2<br>K24 | 3<br>R10 | 3<br>R29 | 4<br>K 4 | 4<br>R38 |
| K 9 | — | — | — | — | — | — |
| K24 | ## | — | — | — | — | — |
| R10 | ## | + | — | — | — | — |
| R29 | ## | — | — | — | — | — |
| K 4 | ## | ## | + | + | — | — |
| R38 | ## | + | — | — | — | — |

horse) as shown in Table 19. Isoagglutinins specific to these antigens were found. Especially agglutinin specific to type 1 erythrocytes were positively detected in all samples excepting type 1 individual out of

thirty-three those tested. Table 20 shows summarized results of the isoagglutination.

Any informations to discuss relationships between these four types and Mn antigens have not been obtained. Phenotypic relations noted in Table 19 would suggest existence of sub-blood types, but additional data should be collected to conclude on allele system definitely. Frequencies of occurrence of these four phenotypes of humpbacks taken from Okinawa area are shown in Table 21 (Cushing *et al.*, 1959).

TABLE 21. FREQUENCY OF OCCURRENCE OF HUMPBACK Ju BLOOD TYPES

| Blood types | | | | No. of whales observed | Locality taken |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | | |
| .010 | .040 | .071 | .879 | 99 | Okinawa |

*Serological constitution of whales from view points of human ABO blood types*

Natural antibodies specific to human ABO blood types were detected on whale serums by means of agglutination reactions. As shown in Table 22, anti-human A ($\alpha'$) agglutinin was detected positively in all species tested, but anti-human B ($\beta'$) agglutinin was found in finback and blue whales only. Agglutinin titers of anti-A reached up to 1 : 2 or 1 : 4 and those of anti-B up to 1 : 8 (Yamaguchi & Fujino, 1952; Fujino, 1953).

TABLE 22. FREQUENCY OF OCCURRENCE OF ANTI-HUMAN A($\alpha'$) AND ANTI-HUMAN B($\beta'$) NATURAL ANTIBODIES IN SERUMS OF VARIOUS SPECIES OF ANIMALS

| Whale species | | Natural antibody | | | | No. of whales tested | Locality taken |
|---|---|---|---|---|---|---|---|
| | | $\alpha'\beta'$ | $\alpha'$ | $\beta'$ | $o'$ | | |
| Toothed whale | blue-white dolphin | .000 | .160 | .000 | .840 | 25 | east side of Izu Penninsula |
| | sperm whale | .000 | .154 | .000 | .846 | 13 | Antarctic |
| Baleen whale | bryde whale | .000 | .188 | .000 | .812 | 16 | Bonin Islands |
| | fin whale | .096 | .065 | .065 | .774 | 31 | northern part of North Pacific |
| | blue whale | .189 | .297 | .000 | .514 | 37 | |
| | humpback whale | .000 | .400 | .000 | .600 | 15 | |

Friedenreich and With (1933) and Iseki and Murakami (1940) state that anti-human B and anti-human A natural antibodies in serums of animal does not have uniform construction in specificity and can be analysed into partial antibodies specific to corresponding partial antigens of human B and A blood groups. While Owen (1954) describes on heterogeneity of antibodies. However no analysis on these points of natural antibody of whales has been undertaken yet.

According to many studies it has been clarified that human blood type

antigens of A, B and O have mosaic constructions of partial antigens and that these partial antigens distribute in erythrocytes and body fluids of animals. Terashima (1942) reported that human A antigen can be analysed into four partial antigens $A_I$, $A_{II}$, $A_{III}$ and $A_{IV}$. Friedenreich and With (1933) subdivide human B antigen into three partial antigens $B_1$, $B_2$ and $B_3$. Recently Furuhata (1957) proposed to substitute $B_I$, $B_{II}$ and $B_{III}$ for three symbols noted above to avoid confusion with those of sub-blood types. Inoue (1943) reported that human O erythrocytes have a mosaic constitution which consists of three partial antigens $O_I$, $O_{II}$ and $O_{III}$.

After analysing B antigen by this method, Fujino (1958) reported that finback erythrocytes have $B'_{IV}$ partial antigen of human B which has simpler structure serologically than $B_{III}$ in guinea pig. Summarized results including additional species are shown in Table 23. Materials and methods in experiments are same as those noted by Fujino (1958). No analysis on blood group substances A and O has been undertaken.

TABLE 23. DISTRIBUTION OF PARTIAL ANTIGENS OF HUMAN B BLOOD TYPE SUBSTANCES

| Whale species | | Partial antigen | No. of whale, tested |
|---|---|---|---|
| Toothed whale | blue-white dolphin | $B_{III}$ and $B_{IV}'$ | 10 |
| | sperm whale | ditto | 25 |
| | baird-beaked whale | ditto | 8 |
| Baleen whale | fin whale | $B_{IV}'$ | 32 |
| | sei whale | ditto | 7 |

Schiff and Sasaki (1932) showed that secretion or non-secretion of blood type substance in human saliva is a hereditary character. Thereafter it has been clarified by many workers that this serological character can be identified with other body fluid than saliva. After analysing saliva of rabbit by the use of antibody specific to human A blood type, Koshino (1938 and 1939) stated that secreter-nonsecreter types can be distinguished in rabbit and that this serological property is closely related to producing ability of anti-human A antibody when used as immune animal. The author tried to analyse secreter-nonsecreter types in sperm whales using mucous membrane of second stomach as material. Human B blood type substance was used as indicator for analysis. After being washed, the mucous membrane of second stomach was ground down and was extracted with equal weight of 1.5 percent saline in refrigerator for 24 hours. Original sample for test were prepared by addition of 1/10 volume of five percent carbolic acid to extracts after boiling for thirty minutes. After being inactivated, anti-human B type immune rabbit serum (agglutinin titer of anti-$B_1 = 1:2560$, Fujino, 1958) was diluted 1 : 20 with saline and was added half volume

of human A type erythrocytes to absorb anti-human species-specific and anti-C agglutinin common to A and B cells.

Series of extracts prepared by successive dilution of original sample with saline was mixed with equal volume of absorbed anti-$B_1$ serum. After two hours' absorption in room temperature, results of agglutination inhibition tests were observed by mixing of human B type erythrocytes as shown in Table 24. It can be seen from this table that extracts of sample nos. 2, 3, 5, 6, 8 and 9 inhibit agglutination of anti-$B_1$ antibody significantly up to 1 : 4 dilution but others inhibit

TABLE 24. ANTI-HUMAN B AGGLUTININ-INHIBITING TESTS BY SALINE EXTRACTS OF STOMACH OF SPERM WHALES

| No. of extracts | Dilution of extracts 1:1 | 1:2 | 1:4 | 1:8 | 1:16 | 1:32 | 1:64 |
|---|---|---|---|---|---|---|---|
| 1 | + | ++ | +++ | +++ | +++ | +++ | +++ |
| 2 | — | — | — | + | ++ | +++ | +++ |
| 3 | — | — | — | ± | + | ++ | +++ |
| 4 | ++ | +++ | +++ | +++ | +++ | +++ | +++ |
| 5 | — | — | — | ± | + | ++ | +++ |
| 6 | — | — | — | ± | + | ++ | +++ |
| 7 | + | ++ | +++ | +++ | +++ | +++ | +++ |
| 8 | — | — | — | — | + | ++ | +++ |
| 9 | — | — | — | + | ++ | ++ | +++ |
| 10 | + | ++ | +++ | +++ | +++ | +++ | +++ |
| Control | +++ | +++ | +++ | +++ | +++ | +++ | +++ |

slightly. These facts seem to show existence of secreter-nonsecreter type in sperm whales. This serological property will serve for analysing of subspecific population in future. Relationship between these characters and known blood types of sperm whales has not been studied yet.

## POPULATION ANALYSIS OF THE NORTH PACIFIC FINBACK WHALES

As regards raciation of the North Pacific fin whales several studies have been published as follows. After discussing seasonal change of localization of whaling grounds, catch statistics and oceanographic informations, Omura (1950) and Kasahara (1950) assumed that in the east (Pacific) and west (Japan sea) sides of Japan distribute different local populations which have different migratory courses each other. Basing upon geographical difference of frequency of occurrence of blood type, Omura (1955) and Fujino (1956) stated that fin whales distribute in areas around Aleutian Islands do not belong to one uniform population, but rather different local populations migrate to area off Kamchatka and area of north of east Aleutian. While Kawakami & Ichihara (1958) stated from results

of marking investigation that both populations in American and Asian sides migrate to same feeding area around Aleutian, but it is not clear whether these populations mingle in this area or are kept isolated each other. After comparing external dimensions of whale body, Ichihara (1957) found significant difference between fin whales from area around Aleutian and those from East China Sea, but does not discuss whether whales taken from these two areas belong to different populations or not. In the present report racial study of whales from these various areas will be discussed by means of population genetics with blood groups and marking investigations.

*Distribution of finback whales in the North Pacific*

Fin whales in the North Pacific have very widely geographical distribution, winter in lower latitude areas for breeding or calving and in summer season migrate northwards for feeding. Whaling grounds are formed in the waters adjacent to California, British Columbia, Alaska, Aleutian Chain, Kuril Islands and Japan during from June to October. Number of finback whales taken in the years 1949 to 1959 are shown in Table 25. In the areas of Okhotsk and Pacific sides of Japan number of catch has remarkably decreased in recent years. Whaling in the East China Sea has been resumed since 1955 after several years' suspension after World War II.

*Population genetics with blood types*

As already stated, several kinds of blood group antigens have been found in finback whales. Four antigens out of these are used for large scale of investigations as markers. Fujino (1956) stated that higher precision in blood typing can be expected in Ju system than in Bp system because of purification of typing reagents and phenotypic relationships. Therefore, Ju system alone has been used since 1956.

Cushing et al. (1959) stated that dosage effects were recognized between homozygous and heterozygous types in Ju system. Thereafter additional dosage effect was observed among heterozygous types as already shown in Table 7. On the other hand original anti-$Ju_2$ immune serums used in the years 1954 to 1959 have been always kept in high agglutinin titers and were used at dilutions 1 : 10 or 1 : 20 in actual typing. Therefore weaker heterozygous types seem to have been scarecely misclassified as $Ju_1$ homozygous type. From above-stated reasons Bp antigens were used for only qualitative comparison between populations and Ju antigens were used for qualitative and quantitative analysis of populations from different localities.

Geographical difference of distributions of Bp and Ju blood type antigens, which were shown in Table 11, will suggest existence of local populations of the North Pacific finback whales. After comparing by

year frequencies of occurrence in various areas, yearly fluctuation can be scarecely seen in the area of north of east Aleutian (area C) but can be recognized in the areas off Kamchatka (area A) and of south of east Aleutian (area B) (see Fig. 2). It can be assumed from these facts that whales which migrate to area C in these successive years, belong to the identical population, and that different populations migrate to areas A and B in different proportions by year. Concerning to this point,

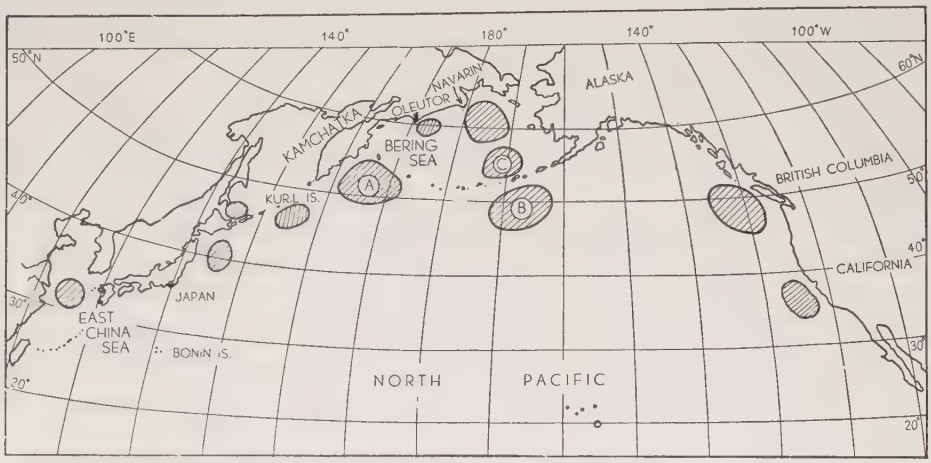



Fig. 1. Whaling grounds in the North Pacific Fin whale.

TABLE 25. NUMBER OF FINBACK WHALES CAUGHT IN VARIOUS AREAS OF THE NORTH PACIFIC, 1949~59

| Area | Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | Sum |
| Bonin | 0 | 0 | 0 | 0 | — | — | — | — | — | — | — | 0[1] |
| Japan West | 1 | 0 | 0 | 22 | 12 | 0 | 225[2] | 277 | 184 | 171 | 80 | 972[3] |
| Japan North-east | 208 | 141 | 209 | 209 | 234 | 197 | 129 | 70 | 76 | 50 | 47 | 1570 |
| Kuril | 53 | 106 | 156 | 241 | 179 | 266 | 219 | 241 | 173 | 328 | 223 | 2185 |
| Kamchatka & Bering (Pelagic) | 64 | 92 | 90 | 447 | 615 | 1554 | 1439 | 1480 | 1486 | 1370 | 1582 | 10219 |
| British Columbia | 105 | 150 | 216 | 240 | 181 | 150 | 120 | 168 | 284 | 573 | 369 | 2556 |
| California | 10 | — | 9 | — | — | — | — | 3 | 22 | 109 | 105 | 258 |
| Sum | 441 | 489 | 680 | 1159 | 1221 | 2167 | 2132 | 2239 | 2225 | 2601 | 2406 | 17760 |

1) Whaling has ceased since 1953.
2) Whaling in the East China Sea has been operated since 1955.
3) Includes thirty-five Whales caught from Tsushima Strait, 1949~53.

Fujino (1953) stated that remarkable seasonal fluctuations of frequency of occurrence of Bp antigens were seen in the area off Kamchatka (area A) in 1952. This fact was confirmed with the results in Ju system obtained in successive years as shown in Table 26.

From these things it can be thought that migratory ranges of different local populations cover this area off Kamchatka and that relative size of these different stocks which actually migrate there fluctuates from year to year.

Number of whales tested in the East China Sea is small, but no remarkable yearly or seasonal fluctuations seem to be recognized judging from daily occurrence of blood types shown in Fig. 3.

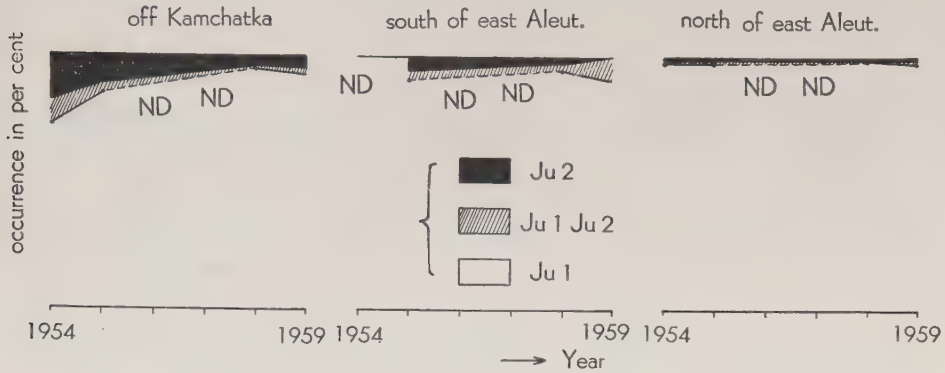



Fig. 2. Yearly fluctuation of frequency of occurrence of Ju blood groups.
ND: No available data

TABLE 26. NON-RANDOM DISTRIBUTION OF BLOOD GROUPS BY YEAR OR BY SEASON IN THE WHALES TAKEN FROM AREAS OFF KAMCHATKA AND SOUTH OF EAST ALEUTIAN.

| Area | Year and season | No. of whales observ. | Blood groups $Ju_1$ | $Ju_1Ju_2$ | $Ju_2$ | Remark |
|---|---|---|---|---|---|---|
| Off Kamchatka | 1954 a | 82 | .646 | .098 | .256 | June |
| | 1954 b | 234 | .765 | .068 | .167 | July~Aug. |
| | 1955 | 113 | .858 | .027 | .115 | May~June |
| | 1958 a | 91 | .989 | .000 | .011 | May 23~June 9 |
| | 1958 b | 28 | .821 | .036 | .143 | July 24~Aug 1 |
| | 1959 | 238 | .929 | .021 | .050 | May 27~June 27 |
| South of east Aleutian | 1955 | 32 | .907 | .031 | .062 | June (13), July (2) & Aug. (17) |
| | 1958 a | 140 | .943 | .021 | .036 | June 10~July 2 |
| | 1958 b | 37 | .946 | .027 | .027 | July 14~July 23 |
| | 1959 | 11 | .909 | .091 | .000 | July 20~29 |

Even in case which yearly fluctuations are seen as stated above, it can be discussed by use of averaged figures of gene frequency whether two populations from areas of both side out of geographically neighbouring three areas mingle in the middle area or not. For this purpose it should be discussed whether continued ratios of corresponding gene frequencies from three areas are proportionate in three alleles or not. Gene frequencies are given in Table 13. Results of calculation in four

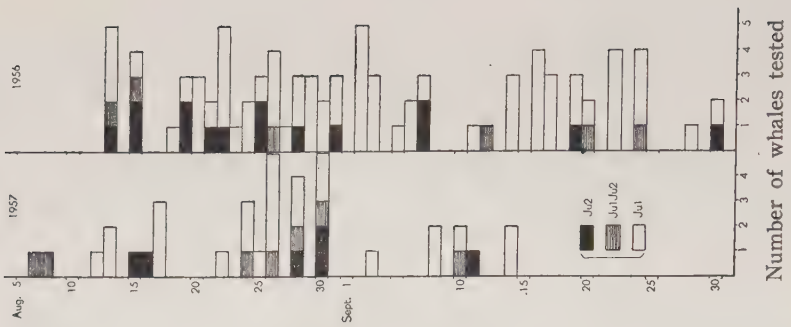



Fig. 3. Occurrence of Ju blood groups in daily catch in East China Sea.

TABLE 27. CORRELATION BETWEEN POPULATIONS TAKEN FROM NEIGHBOURING THREE AREAS REVEALED BY GENE FREQUENCIES

| | Combination of neighbouring three areas | Allele system | Gene freq. obs. | Gene freq. exp.[2] | Ratio of mingl.[1] b | Ratio of mingl.[1] 1−b | | Freq. of phenotype obs. | Freq. of phenotype exp.[2] | $\chi^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| a) | East China Sea | A | $p$ .062 | .087 | .28 | .72 | $Ju_1$ | 663 | 684.6 | |
| | Kamchatka | | $q$ .600 | .630 | .65 | .35 | $Ju_1Ju_2$ | 33 | 38.5 | 13.14 |
| | East Aleutian (Sum of north & south) | | $r$ .338 | .283 | .77 | .23 | $Ju_2$ | 90 | 62.9 | |
| | | | | *average | .57 | .43 | | 786 | | |
| | | B | $p$ .662 | .686 | .77 | .23 | $Ju_1$ | | 644.5 | |
| | | | $q$ .032 | .059 | .34 | .66 | $Ju_1Ju_2$ | | 63.7 | 17.24 |
| | | | $r$ .306 | .254 | .94 | .06 | $Ju_2$ | | 77.8 | |
| | | | | *average | .68 | .32 | | | | |
| b) | East China Sea | A | $p$ .062 | .090 | −.17 | 1.17 | $Ju_1$ | 663 | 693.3 | |
| | Kamchatka | | $q$ .600 | .649 | .52 | .48 | $Ju_1Ju_2$ | 33 | 37.7 | 24.18 |
| | South of east Aleut. | | $r$ .338 | .265 | .69 | .31 | $Ju_2$ | 90 | 55.0 | |
| | | | | *average | .35 | .65 | | 786 | | |
| | | B | $p$ .662 | .679 | .69 | .31 | $Ju_1$ | | 642.9 | |
| | | | $q$ .032 | .058 | .22 | .78 | $Ju_1Ju_2$ | | 62.1 | 15.26 |
| | | | $r$ .306 | .262 | .91 | .09 | $Ju_2$ | | 81.0 | |
| | | | | *average | .61 | .39 | | | | |
| c) | East China Sea | A | $p$ .062 | .086 | .36 | .64 | $Ju_1$ | 663 | 683.0 | |
| | Kamchatka | | $q$ .600 | .628 | .67 | .33 | $Ju_1Ju_2$ | 33 | 38.5 | 11.45 |
| | North of east Aleut. | | $r$ .338 | .286 | .78 | .22 | $Ju_2$ | 90 | 64.5 | |
| | | | | *average | .60 | .40 | | 786 | | |
| | | B | $p$ .662 | .687 | .78 | .22 | $Ju_1$ | | 644.5 | |
| | | | $q$ .032 | .060 | .35 | .65 | $Ju_1Ju_2$ | | 64.5 | 18.11 |
| | | | $r$ .306 | .253 | .94 | .06 | $Ju_2$ | | 77.0 | |
| | | | | *average | .69 | .31 | | | | |
| d) | Kamchatka | A | $p$ .071 | .051 | 1.26 | −.26 | $Ju_1$ | 206 | 198.5 | |
| | South of east Aleut. | | $q$ .739 | .682 | .47 | .53 | $Ju_1Ju_2$ | 6 | 5.9 | 3.99 |
| | North of east Aleut. | | $r$ .190 | .267 | .35 | .65 | $Ju_2$ | 8 | 15.6 | |
| | | | | *average | .69 | .31 | | 220 | | |
| | | B | $p$ .801 | .801 | .35 | .65 | $Ju_1$ | | 206.4 | |
| | | | $q$ .017 | .014 | .48 | .52 | $Ju_1Ju_2$ | | 4.8 | 0.37 |
| | | | $r$ .173 | .185 | .33 | .67 | $Ju_2$ | | 8.8 | |
| | | | | *average | .39 | .61 | | | | |

1) Ratio of mingling in the middle area of populations from western and eastern areas.
2) Calculated from figures of populations from areas of both side and averaged ratio of mingling.

combinations of neighbouring three areas among which gene frequencies reveal successive gradients are shown in Table 26. These include four cases of a) East China Sea : area A : sum of areas B and C, b) East China Sea : area A : area B, c) East China Sea : area A : area C, and d) area A : area B : area C.

From Table 26 it was denied that populations from both sides' areas mingle in middle area in any three cases a), b), and c) out of four through A or B allele systems. While in case of d) possibility of mingling seem to be assumed through B allele system only. This will be discussed later more in detail together with results of marking investigations. As results of emigration of marked whales show that some degree of minglings occur between west and east areas around Aleutian, it can be concluded that whales from East China Sea belong to a local populations which nearly isolated from populations that migrate to areas around Aleutian Chains. Results from areas off Navarin and Olyutorskiy Peninsulas are excluded from calculations because of scantiness of data available.

*Ratios of mingling of different populations calculated from blood type gene frequencies and rate of recapture of marked whales*

A. Rate of emigration of populations calculated from marking return. A part of marking investigations, which has been undertaken in the north Pacific since 1949, was already reported by Omura & Kawakami (1956) and Kawakami & Ichihara (1958). As shown in Table 28, number of finback whales recorded as 'Hit' reach up to 14 in the areas off

TABLE 28. NUMBER OF FINBACK WHALES MARKED IN VARIOUS AREAS OF THE NORTH PACIFIC, 1949~1959*

| Area | Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | Sum |
| Bonin | | | | 1 | | | | | | | | 1 |
| Japan, Pacific | 7 | | 1 | | 5 | | | | | | | 13 |
| Kamchatka | | | | | 22[1] | 4 | 4[2] | 1 | 2 | 28 | | 61 |
| East Aleutian South | | | | | | 18[3] | 15 | 16 | 10 | 8 | 10 | 77 |
| East Aleutian North | | | | | | 210[6] | 32 | 57 | 34[4] | 28 | 16[5] | 377 |
| North of Pribilof and Navarin | | | | | | 3 | 1 | | 9 | | | 13 |
| Sum | 7 | 0 | 1 | 1 | 27 | 235 | 52 | 74 | 55 | 64 | 26 | 542 |

* Includes whales recorded as 'Hit' only. 1), 2), 3), 4) and 5) include each one whale which was not recorded as 'Hit' but was recovered in successive years. 6) includes same type of three whales as above-noted.

Bonin Islands and Pacific side of Japan and to 528 in the area around Aleutian Islands. Seventy whales out of these have been recaptured in the areas around Aleutians, but no recovery has been reported from areas of East China Sea, north-east side of Japan, around Kuril Islands, off British Columbia and California in which whalings have been operated.

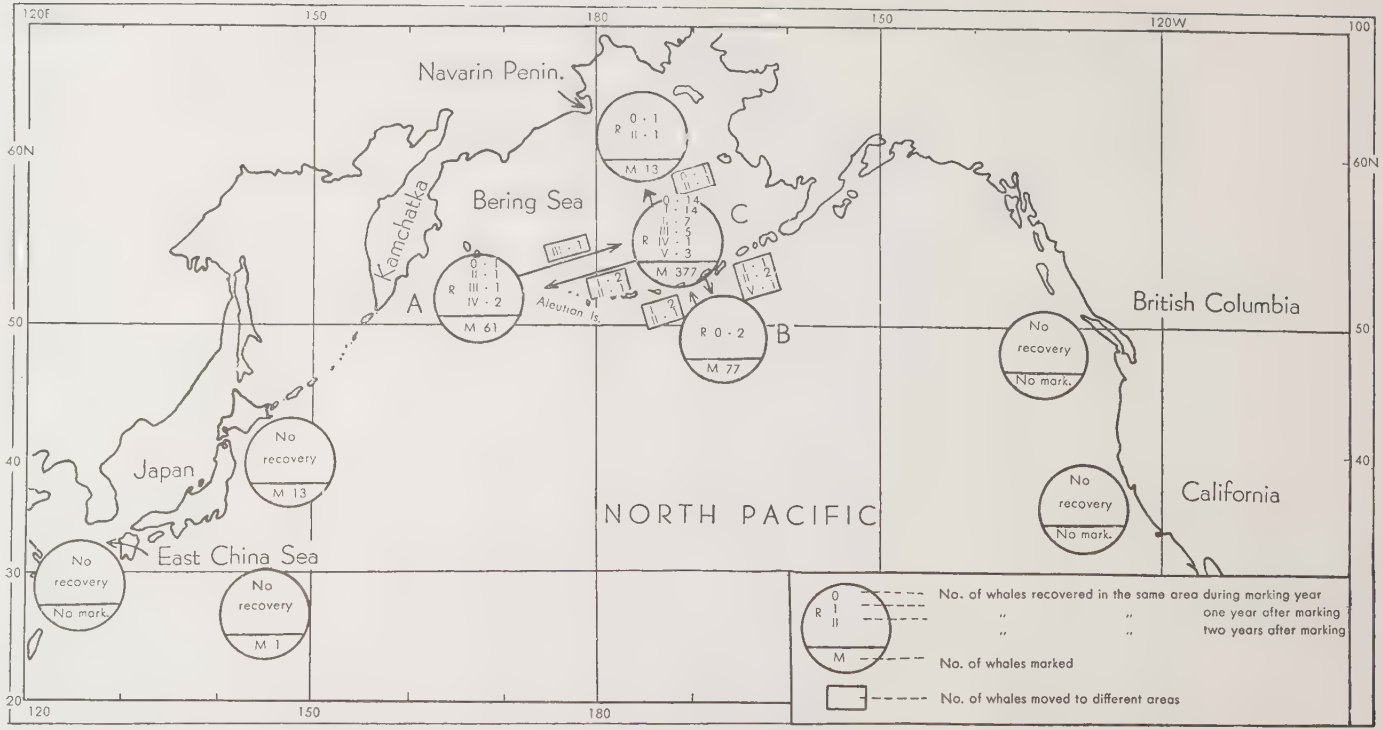



Fig. 4. Summarized results of movements of marked finback whales in the North Pacific (1953~1959).

Fig. 4 outlines interrelations among various whaling areas revealed by results of movement of marked whales. It can be thought to suggest existence of local populations that in spite of fairly large number of whales are taken from various areas noted above in every year no recovery of marker has been reported from these areas excepting those around Aleutians. Especially regarding to relations between populations in East China Sea and those around Aleutians, above-stated facts could be interpreted to confirm that the former is isolated from the latter as already concluded from blood typing investigations.

Relations among various areas around Aleutians will be analysed in following part. As shown in Fig. 4, 5 and 1 out of 61 whales marked in area A were recaptured in the same area and area C respectively. 44, 3, 2 and 4 out of 377 whales marked in area C has been recaptured in the same, A, north of Pribilof and off Navarin, and B areas respectively. Out of 77, 2 and 3 whales marked in area B have been recaptured in the same and C areas. Additional recaptures of one and three whales from those marked in areas C and B respectively were reported. As their markers, however, were recovered from freezing ship or oil-cooker of factory ship after treatment of whale body it is not clear whether these whales were recaptured from areas B or C. Judging from non-random geographical distribution in blood type gene frequency noted already, it can be thought that population which migrates to area C belong to different those migrate to area A, but above-stated results of marked whales show that mingling occurs in part between east and west populations. When two populations of west and east sides are temporarily called as I and II, above-stated situations may be interpreted as follows. These populations I and II are kept isolated each other in wintering breeding season and their feeding migratory ranges overlap in part in the areas around Aleutian Islands in summer season.

As Japanese pelagic whaling for baleen whales in the North Pacific has been operated by one company's whaling fleet, conditions at recovery of markers can be thought to be approximately identical by year and by area. Therefore problems of mingling between populations I and II in the areas A and C could be discussed quantitatively basing upon results of emigration of marked whales. Relative size of populations I and II which actually migrate to areas A and C can be calculated as average for periods of investigation from blood type gene frequencies and rate of emigration which is obtained as relative figures of rate of recapture against total catch in each area. As number of whales recaptured in the year of marking is remarkably effected by the season of marking and whaling operation, they are excluded from calculation.

Symbols listed in ' A Standard Terminology and Notation for Fishery Dynamics ' (Holt et al., 1959) are applied to calculating results of marking investigation, and some other additional terms and symbols are adopted.

If average rate of recapture of whales marked in area A against catch in areas A and C in successive years after marking is given as $r_1^1$ and $r_2^1$, and those of whales marked in area C against catch in area A and C is given as $r_1^2$ and $r_2^2$, following representation will be possible.

Rate of return of whales to area A: $\dfrac{r_1^1}{r_1^1+r_2^1}$

, rate of emigration of whales from areas A to C: $\dfrac{r_2^1}{r_1^1+r_2^1}$

, rate of return of whales to area C: $\dfrac{r_2^2}{r_1^2+r_2^2}$

, and rate of emigration of whales from areas C to A: $\dfrac{r_1^2}{r_1^2+r_2^2}$.

Whales against which marking investigations have been actually carried out in the various areas around Aleutian Islands should be thought to consist of not pure populations but rather parts of both populations I and II. If marking investigations in areas A and C, however, could be thought to have been undertaken against unmingled populations I and II respectively for convenience to calculation, ratios of mingling of both populations in areas A and C can be given by following formulas,

$$\left.\begin{aligned} &\text{ratio of mingling in area A}: \quad m^A_{\mathrm{I:II}} = N_1 \frac{r_1^1}{r_1^1+r_2^1} : N_2 \frac{r_1^2}{r_1^2+r_2^2} \\ &\text{ratio of mingling in area C}: \quad m^C_{\mathrm{I:II}} = N_1 \frac{r_2^1}{r_1^1+r_2^1} : N_2 \frac{r_2^2}{r_1^2+r_2^2} \end{aligned}\right\} \qquad (4)$$

, where $N_1$ and $N_2$ are relative sizes of parts of populations I and II respectively which actually migrate to areas A and C.

Figures of $r_1^1$, $r_2^1$, $r_1^2$, and $r_2^2$ can be calculated as follows. At first various symbols necessary for formulation are given. Term of $u$ means average rate of recapture of whales, marked in area C in a year, against number of catch in area C in successive years. Number of catch, of whales recaptured, and of survivor in area C in successive years after marking are represented as follows.

| Lapse of years after marking | | 0 | 1 | 2 ⋯ $x$ |
|---|---|---|---|---|
| In area C, | no. of whales recaptured | $R_0$ | $R_1$ | $R_2 \cdots R_x$ |
| | no. of survivor of initial stock in catch | $C_0'$ | $C_1'$ | $C_2' \cdots C_x'$ |

As it can be assumed that total number of whales recaptured up to $x$ years after marking proportionates to total number of survivor of

initial stock, when marked, in catch, $u$ will be given as rate of the former against the latter which is averaged for the figures of successive years as follows.

$$u=\frac{1}{x}\cdot\frac{1}{f}\left(\frac{R_1}{C'_1}+\frac{R_1+R_2}{C'_1+C'_2}+\cdots+\frac{R_1+R_2+\cdots+R_x}{C'_1+C'_2+\cdots+C'_x}\right). \quad (5)$$

After averaging figures of $u$ for different years with weight, $r_2^2$ in formula 4 will be obtained through formula 5.

$$r_2^2=\frac{2g}{x(x+1)}\left(\frac{u_0}{T_0-R'_0}\cdot x+\frac{u_1}{T_1-R'_1}\cdot(x-1+\cdots+\frac{u_{x-1}}{T_{x-1}-R'_{x-1}}\cdot 1\right). \quad (6)$$

, where $T$ means number of whales 'hit' in area C, $R'$ means total number of whales recaptured in the year of marking, that is, includes whales recaptured after emigrating to different areas, $f$ means rate of recovery of marker from whales actually recaptured, and $g$ means rate of confirming whales reported as 'Hit' against number of whales effectively marked. Figures of $f$ and $g$ are given as constant by year and by area. When various figures of area A are adopted to $T$, $C'$ and $R'$ in formulas 5 and 6, $r_1^1$ can be calculated by the same way as stated-above. To calculate $r_1^2$, figures of area C are adopted to $T$ and those of area A are used for $R'$ and $C'$ in the same formulas.

Various figures used for these calculations such as number of whales hit, of those recaptured and of catch are shown in Tables 29 and 30. Calculation of number of survivor $C'$ from number of catch $C$ will be discussed later. Number of marked whales in Table 29 include whales reported as 'Hit' only and does not include finback whales recaptured from those reported as 'No verdict', 'Miss' or 'misconceived as different species' when marked. As remarked in the table, three and one whales marked in areas B and C respectively are excluded from 'number of whales recaptured' in this table, because their markers were recovered from cooker or refrigerated ship and their localities and dates of recapture are indefinite.

Figure of $f$ was estimated from the experimental results on recovery of markers reported by Kawakami & Nasu (1956) as shown in Table 31. They stated that significant difference of rate of recovery was seen between standard type dart and dart with streamer in their experiments. In actual case, however, most streamer is fallen off from dart when recovered. Therefore $f$ is calculated for all kinds of dart ($1/f$ correction) from number of dart recovered on the treating deck of factory ship among standard type dart shot into finback whales, that is, $f=17/35=0.485$. In actual marking investigation, whales recaptured can be divided into two cases in which their markers were recovered from whales re-

TABLE 29. NUMBER OF FIN WHALES MARKED AND RECAPTURED

| Marked in the areas: | | Recaptured in the areas: Off Kamchatka 1953 | 54 | 55 | 56 | 57 | 58 | 59 | South of east Aleut. 1953 | 54 | 55 | 56 | 57 | 58 | 59 | North of east Aleut. 1953 | 54 | 55 | 56 | 57 | 58 | 59 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Off Kamchatka | 1953 | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — |
| | 54 | | — | — | — | — | — | — | | — | — | — | — | — | — | | — | — | — | — | — | — |
| | 55 | | | — | — | — | — | 2 | | | — | — | — | — | — | | | — | — | — | — | — | — |
| | 56 | | | | — | — | — | — | | | | — | — | — | — | | | | — | — | — | — | — |
| | 57 | | | | | 1 | -- | 1 | | | | | — | — | — | | | | | — | — | — | — |
| | 58 | | | | | | — | — | | | | | | — | — | | | | | | — | — | — |
| | 59 | | | | | | | — | | | | | | | — | | | | | | | — | — |
| South of east Aleutian | 1953 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 54 | | — | — | — | | — | — | | — | — | — | — | — | — | | — | — | 1 | — | — | — | — |
| | 55 | | | — | — | | — | — | | | 2 | — | — | — | — | | | — | 1 | — | — | — | — |
| | 56 | | | | — | — | — | — | | | | — | — | — | — | | | | — | — | — | — | — | — |
| | 57 | | | | | — | — | — | | | | | — | — | — | | | | | — | 1 | — | — |
| | 58 | | | | | | — | — | | | | | | — | — | | | | | | — | — | — |
| | 59 | | | | | | | — | | | | | | | — | | | | | | | — | — |
| North of east Aleutian | 1953 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 54 | | — | — | — | — | — | — | | — | — | — | — | — | 1 | | 7 | 7 | 2 | 1 | 1 | 3 |
| | 55 | | | — | 1 | 1 | — | — | | | — | — | 2 | — | — | | | 2 | — | 1 | 1 | — |
| | 56 | | | | — | — | — | — | | | | — | — | — | — | | | | — | — | 1 | 3 |
| | 57 | | | | | — | 1 | — | | | | | — | 1 | — | | | | | — | 6 | 3 |
| | 58 | | | | | | — | — | | | | | | — | — | | | | | | 1 | 1 |
| | 59 | | | | | | | — | | | | | | | — | | | | | | | 4 |
| North of Pribilof and off Navarin | 1953 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 54 | | — | — | — | — | — | — | | — | — | — | — | — | — | | | — | — | — | — | — | — |
| | 55 | | | — | — | — | — | — | | | — | — | — | — | — | | | | — | — | — | — | — |
| | 56 | | | | — | — | — | — | | | | — | — | — | — | | | | | — | — | — | — |
| | 57 | | | | | — | — | — | | | | | — | — | — | | | | | | — | — | — |
| | 58 | | | | | | — | — | | | | | | — | — | | | | | | — | — | — |
| | 59 | | | | | | | — | | | | | | | — | | | | | | | — | — |
| Sum | | | | | 2 | 2 | 1 | 3 | | | 2 | | 2 | 1 | 1 | | 7 | 9 | 5 | 2 | 11 | 14 |

a) Includes whales recorded as 'Hit' only. There are one additional recapture from

b) A marker (no. 4452), which no information on marking was recorded, is excluded from

c), d) Marker no. 6860 was recovered in the year 1959. Markers of nos. 6859 and 7269

TABLE 30. NUMBER OF FINBACK WHALES TAKEN BY JAPANESE FLEET IN VARIOUS AREAS AROUND ALEUTIAN ISLANDS AND BERING SEA

| Year | Area: Off Kamchatka | East Aleutian: South | East Aleutian: North | North of Pribilof | Off Navarin | Off Olyutorskiy | Sum |
|---|---|---|---|---|---|---|---|
| 1952 | 213 | | | | | | 213 |
| 53 | 470 | | | | | | 470 |
| 54 | 564 | 168 | 584 | | | | 1316 |
| 1955 | 148 | 35 | 1177 | | | | 1360 |
| 56 | 595 | 46 | 774 | | | | 1415 |
| 57 | 280 | 500 | 286 | 158 | 174 | 6 | 1404 |
| 58 | 269 | 442 | 298 | | 275 | 47 | 1331 |
| 59 | 694 | 53 | 703 | | | | 1450 |
| Sum | 3233 | 1244 | 3822 | 158 | 449 | 53 | 8959 |

IN THE VARIOUS AREAS AROUND ALEUTIAN ISLANDS, 1953~1959

| North of Pribilof and off Navarin | | | | | | | Sum of recapture | Number of whales marked | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|
| 1953 | 54 | 55 | 56 | 57 | 58 | 59 | | recorded as 'Hit', $T_i$[a] | corrected $T_i \times 1/g$ | |
| — | — | — | — | — | — | — | 2 | 21[1] | 26.2 | |
| | — | — | — | — | — | — | | 4 | 5.0 | |
| | | — | — | — | — | — | 2 | 3[2] | 3.7 | |
| | | | — | — | — | — | | 1 | 1.2 | |
| | | | | — | — | — | 2 | 2 | 2.5 | |
| | | | | | — | — | | 28 | 34.9 | |
| | | | | | | — | | 0 | 0.0 | |
| — | — | — | — | — | — | — | | 0 | 0.0 | |
| | — | — | — | — | — | — | 1 | 17[3] | 21.2 | |
| | | — | — | — | — | — | 3 | 15 | 18.7 | One whale (mark no. J6149) recaptured from areas B or C in 1958, isnot included in no. of recapture. |
| | | | — | — | — | — | | 16 | 20.0 | |
| | | | | — | — | — | 1 | 10 | 12.5 | |
| | | | | | — | — | | 8 | 10.0 | Two markers of no. 6860 & 6859, recovered from cooker, are not included in no. of recovery[c]. |
| | | | | | | — | | 10 | 12.5 | |
| — | — | — | — | — | — | — | | 0 | 0.0 | |
| | — | — | — | — | — | — | 22 | 206[6] | 256.6 | |
| | | — | — | 1 | — | — | 9 | 32 | 39.9 | |
| | | | — | — | — | — | 4 | 57 | 71.0 | One marker of no. 7269, recovered from refrigerated ship, is not included in no. of recovery[d]. |
| | | | | 1 | — | — | 12 | 33[4] | 41.0 | |
| | | | | | — | — | 2 | 28 | 34.9 | |
| | | | | | | — | 4 | 15[5] | 18.7 | |
| — | — | — | — | — | — | — | | 0 | 0.0 | |
| | — | — | — | — | — | — | | 3 | 3.8 | |
| | | — | — | 1 | — | — | 1 | 1 | 1.2 | |
| | | | — | — | — | — | | 0 | 0.0 | |
| | | | | 1 | — | — | 1 | 9 | 11.2 | |
| | | | | | — | — | | 0 | 0.0 | |
| | | | | | | — | | 0 | 0.0 | |
| | | | | 4 | | | 66 | 519[b] | 646.7 | |

whales not recorded as 'Hit' in each of 1), 2), 3), 4), 5) and four those in 6) respectively.
number of marking and recapture.
were recovered in the same year of marking.

TABLE 31. RATE OF RECOVERY OF MARKERS*

| | Fin whale | | Humpback whale | | Sperm whale | |
|---|---|---|---|---|---|---|
| | no. of hit | no. of recovery | no. of hit | no. of recovery | no. of hit | no. of recovery |
| With streamer | 21 | 15 | 2 | 1 | 11 | 10 |
| Without streamer | 35 | 21[1] | 3 | 3 | 20 | 18[2] |

1) Includes four markers recovered from refrigerated ship.
2) Includes two markers recovered from refrigerated ship.
* Cited from Kawakami & Nasu (1956).

corded as 'Hit' and from those not so recorded. Then $g$ was calculated from Table 31 as a rate of number of whales recaptured from the former against total number of recapture, that is, $g=\frac{66-9}{66+4+1}=\frac{57}{71}=0.803$ ($1/g$ correction). This denominator includes four whales of which localities

recaptured are indefinite and one whale recaptured from those on which no information is recorded at the time of marking.

$C'$ in formula 5 was calculated from number of catch $C$ in each year which were given in Table 30. While initial stock at the year of marking gradually decreases with lapse of years through natural mortality and catch, it is recruited from younger generation in population. If stock number, number of recruitment and number of survivor of initial stock at the year of marking are represented as follows, stock in each year consists of survivor and recruit, and rate of recruit $r$ and survival rate $S$ have constant figures through full period of investigation, then formulas 7, 8 and 9 can be introduced.

| Lapse of year after marking | 0 | 1 | 2 ⋯ $x$ |
|---|---|---|---|
| Stock number | $N_0$ | $N_1$ | $N_2 \cdots N_x$ |
| Number of annual recruitment | | $R_1$ | $R_2 \cdots R_x$ |
| Number of survivor of initial stock when marked | | $N_1'$ | $N_2' \cdots N_x'$ |

$$r=\frac{R_1}{N_1}=\frac{R_2}{N_2}=\cdots=\frac{R_x}{N_x}, \tag{7}$$

$$S=\frac{N_1-R_1}{N_0}=\frac{N_2-R_2}{N_1}=\cdots=\frac{N_x-R_x}{N_{x-1}}, \tag{8}$$

$$N_x'=N_0 \cdot S^x . \tag{9}$$

From formulas 7 and 8, $N_x=N_0\left(\frac{S}{1-r}\right)^x$. Eliminating $N_0$ from this relation and formula 9,

$$N_x'=N_x(1-r)^x . \tag{10}$$

If survival rates in sample of catch represent those of whole population,

$$\frac{C_x'}{C_x}=\frac{N_x'}{N_x}=(1-r)^x . \tag{11}$$

When stock is in a stabilized state, $S+r=1$. From this relation and formula 11,

$$C_x'=S^x \cdot C_x . \tag{12}$$

Survival rates $S$ used for formula 12 are estimated from frequency distributions of number of corpus albicans in pregnant females taken and from those of number of lamination of ear-plug in each area. Data on ovaries used include major part of pregnant females taken during from 1952 to 1959, and data on ear-plug used base on the results collected in the three years 1957, 58 and 59 as shown in Table 32 and 34. At first it was discussed whether figures of survival rate

show significant differences or not during periods from 1952 to 1959 in which Japanese pelagic whalings have been operated. As regards averaged number of ovulation in a breeding cycle, Laws & Purves (1956) offered figure of approximate 2.8 for Atlantic finbacks, Purves & Mountford (1959) obtained approximately same figure for Antarctic finbacks. While, Nishiwaki et al. (1958) reported figures of 1.6 and 1.8 for the North Pacific and Antarctic finbacks respectively, so that significant discrepancy between results reported by both authors for Antarctic finbacks. In relation to this problem Laws (1960) states, ' There is still some uncertainty about the interpretation of the lamination of ear-plug at present.' Therefore age composition are obtained from frequency distribution of number of corpus albicans shown in Table 32 for two cases inwhich averaged number of ovulation is 1.6 or 2.8, and total survival rate $S$ is calculated from these age compositions in two cases as rate of sum of five years' and older survivors against sum of four years' and older survivors as shown in Table 33. In Figure 5 survival curves for whole areas around Aleutian Islands against averaged number of ovulation 1.6 are drawn separately for three successive periods of years 1952–55, 1956–57, and 1958–59. Total survival rates for these three periods reveal gradual increase as shown by figures 0.8783, 0.9008 and 0.9095. Even if selective catching larger whales would effect upon the above-stated trend because of steadiness in whaling operation in recent years, it might be impossible to conclude that the north Pacific finback stock have depleted remarkably at present. After discussing separately by areas A, B and C, same trends can be clearly recognized. Of course these facts can be seen also in another case that averaged number of ovulation is 2.8 as shown in Table 35. In consequence, it may be possible for convenience of calculation to regard that the north Pacific finback stocks are nearly in a stabilized state. Then, $C'_x$ in formula 5 will be calculated by formula 12, and total survival rates $S$ can be given as averaged figures through whole periods for various areas. Total survival rates calculated from frequency distribution of number of lamination of ear-plug are shown in Table 35. It can be seen from this table that these figures are mostly consistent with those calculated from ovarian data in a case of averaged number of ovulation 1.6. According to Baranov (1918) mortality rates of a population may be calculated from the slope of the right limb of a frequency curve of ages. But frequencies of occurrence at peak and successive older several age groups in right limb of this curve drawn by ear-plug data may be assumed to be not representative of population because of size limitation in regulation of whaling. Therefore, number of survivors in these age groups were corrected by geometrical mean of survival rate calculated

from successive older three age groups. Total survival rate $S$ was obtained as rate of survivors of age group $t_{c+1}$ and older against those of minimum catchable age $t_c$ and older. No significant difference in figure

TABLE 32. FREQUENCY DISTRIBUTION OF NUMBER OF CORPUS ALBICANS

| No. of corpora albicans | Off Kamchatka (A) | | | | | | | | South of east Aleutian (B) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952~54 | | 1955~56 | | 1957~59 | | Sum | | 1954~55 | | 1956~57 | | 1958~59 | | Sum | |
| 0 | 23 | | 13 | | 25 | | 61 | | 6 | | 12 | | 10 | | 28 | |
| 1 | 26 | | 9 | | 20 | | 55 | | 11 | | 9 | | 16 | | 36 | |
| 2 | 30 | 25.6 | 9 | 10.2 | 21 | 22.6 | 60 | 58.4 | 4 | 5.2 | 16 | 12.4 | 7 | 8.6 | 27 | 26.2 |
| 3 | 28 | 25.0 | 7 | 10.4 | 27 | 22.8 | 62 | 58.2 | 3 | 5.0 | 16 | 12.4 | 4 | 8.2 | 23 | 25.6 |
| 4 | 21 | 24.0 | 13 | 10.2 | 20 | 21.2 | 54 | 55.4 | 2 | 3.4 | 9 | 12.4 | 6 | 7.4 | 17 | 23.2 |
| 5 | 20 | 21.4 | 14 | 11.8 | 16 | 20.4 | 60 | 53.6 | 5 | 3.4 | 12 | 11.6 | 8 | 7.2 | 25 | 22.2 |
| 6 | 21 | 19.4 | 8 | 10.8 | 12 | 18.6 | 41 | 48.8 | 3 | 3.8 | 9 | 10.0 | 12 | 7.0 | 24 | 20.8 |
| 7 | 17 | 18.0 | 17 | 9.8 | 17 | 20.0 | 51 | 47.8 | 4 | 3.6 | 12 | 9.6 | 6 | 6.8 | 22 | 20.0 |
| 8 | 18 | 16.2 | 2 | 8.8 | 18 | 18.0 | 38 | 43.0 | 5 | 3.0 | 8 | 8.8 | 3 | 5.8 | 16 | 17.6 |
| 9 | 14 | 13.6 | 8 | 8.4 | 27 | 18.2 | 49 | 40.2 | 1 | 3.0 | 7 | 8.6 | 5 | 4.0 | 13 | 15.6 |
| 10 | 11 | 10.8 | 9 | 5.6 | 16 | 17.6 | 36 | 34.0 | 2 | 2.2 | 8 | 7.6 | 3 | 3.8 | 13 | 13.6 |
| 11 | 8 | 7.6 | 6 | 5.8 | 13 | 15.8 | 27 | 28.6 | 3 | 1.2 | 8 | 6.4 | 3 | 3.8 | 14 | 11.4 |
| 12 | 3 | 5.6 | 3 | 4.6 | 14 | 11.6 | 20 | 21.8 | | 1.2 | 7 | 5.2 | 5 | 3.0 | 12 | 9.4 |
| 13 | 2 | 3.8 | 3 | 3.6 | 9 | 9.8 | 14 | 17.2 | | 0.4 | 2 | 5.0 | 3 | 2.6 | 5 | 7.0 |
| 14 | 4 | 2.4 | 2 | 3.2 | 6 | 8.0 | 12 | 13.6 | 1 | 0.4 | 1 | 2.6 | 1 | 2.0 | 3 | 5.0 |
| 15 | 2 | 2.2 | 4 | 2.4 | 7 | 5.8 | 13 | 10.4 | | 0.6 | 2 | 1.6 | 1 | 1.0 | 3 | 3.2 |
| 16 | 1 | 1.8 | 2 | 2.0 | 4 | 4.8 | 7 | 8.6 | 1 | 0.6 | 1 | 1.2 | | 0.4 | 2 | 2.2 |
| 17 | 2 | 1.0 | 1 | 1.6 | 3 | 3.6 | 6 | 6.2 | 1 | 0.4 | 2 | 1.2 | | 0.2 | 3 | 1.8 |
| 18 | | 0.6 | 1 | 1.0 | 4 | 2.4 | 5 | 4.0 | | 0.4 | | 1.0 | | | | 1.4 |
| 19 | | 0.4 | | 0.8 | | 1.6 | | 2.8 | | 0.4 | 1 | 1.0 | | | 1 | 1.4 |
| 20 | | | 1 | 0.6 | 1 | 1.2 | 2 | 1.8 | | 0.2 | 1 | 0.6 | | | 1 | 0.8 |
| 21 | | 0.2 | 1 | 0.4 | | 0.4 | 1 | 1.0 | 1 | 0.2 | 1 | 0.6 | | | 2 | 0.8 |
| 22 | | 0.2 | | 0.4 | 1 | 0.4 | 1 | 1.0 | | 0.2 | | 0.6 | | | | 0.8 |
| 23 | 1 | 0.2 | 1 | 0.4 | | 0.2 | 1 | 0.8 | | 0.2 | 1 | 0.4 | | | 1 | 0.6 |
| 24 | | 0.2 | | 0.2 | | 0.2 | | 0.6 | | | | 0.2 | | | | 0.2 |
| 25 | | 0.2 | | 0.2 | | | 1 | 0.4 | | | | 0.2 | | | | 0.2 |
| 26 | | | | 0.2 | | | | 0.2 | | | | | | | | |
| 27 | | | | 0.2 | | | | 0.2 | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | 0.2 | | | | 0.2 |
| 32 | | | | | | | | | | | | 0.2 | | | | 0.2 |
| 33 | | | | | | | | | | | 1 | 0.2 | | | 1 | 0.2 |
| 34 | | | | 0.2 | | | | 0.2 | | | | 0.2 | | | | 0.2 |
| 35 | | | | 0.2 | | | | 0.2 | | | | 0.2 | | | | 0.2 |
| 36 | | | 1 | 0.2 | | | 1 | 0.2 | | | | | | | | |
| 37 | | | | 0.2 | | | | 0.2 | | | | | | | | |
| 38 | | | | 0.2 | | | | 0.2 | | | | | | | | |
| 39 | | | | | | | | | | | | | | | | |
| 40 | | 0.2 | | | | | | 0.2 | | | | | | | | |
| 41 | | 0.2 | | | | | | 0.2 | | | | | | | | |
| 42 | 1 | 0.2 | | | | | 1 | 0.2 | | | | | | | | |
| 43 | | 0.2 | | | | | | 0.2 | | | | | | | | |
| 44 | | 0.2 | | | | | | 0.2 | | | | | | | | |

$S$ was seen in two cases which three or four age were adopted as minimum catchable age $t_c$. As total survival rates calculated from ear-plug's data were consistent with one of two those calculated from ovarian data, figures calculated from only ovarian data were used for actual calculation of formula 12.

In actual marking investigation in the ocean, whales smaller than legal limit must be marked also. This may be assumed from figure 6 showing comparison between estimated size distribution of whales when

OF PREGNANT FINBACK FEMALES (OBSERVED AND SMOOTHED FIGURES)

| North of east Aleutian (C) | | | | | | | | Sum of three areas | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1954~55 | | 1956~57 | | 1958~59 | | Sum | | 1952~55 | | 1956~57 | | 1958~59 | | sum | |
| 56 | | 26 | | 34 | | 116 | | 89 | | 54 | | 62 | | 205 | |
| 63 | | 28 | | 20 | | 111 | | 102 | | 48 | | 52 | | 202 | |
| 37 | 47.4 | 34 | 22.8 | 21 | 21.6 | 92 | 91.8 | 75 | 81.0 | 61 | 50.0 | 43 | 46.6 | 179 | 177.6 |
| 51 | 43.4 | 21 | 21.6 | 15 | 16.8 | 87 | 81.8 | 84 | 76.6 | 52 | 46.8 | 36 | 42.2 | 172 | 165.6 |
| 30 | 35.4 | 11 | 17.8 | 18 | 15.4 | 59 | 68.6 | 55 | 66.0 | 35 | 42.6 | 40 | 38.6 | 130 | 147.2 |
| 36 | 32.0 | 14 | 12.2 | 10 | 13.8 | 50 | 58.0 | 67 | 60.2 | 38 | 36.8 | 40 | 36.8 | 145 | 133.8 |
| 23 | 23.6 | 9 | 9.0 | 13 | 12.0 | 45 | 45.2 | 49 | 49.8 | 27 | 31.0 | 34 | 36.0 | 110 | 116.8 |
| 20 | 19.4 | 6 | 7.4 | 13 | 10.6 | 39 | 37.4 | 46 | 44.0 | 32 | 28.6 | 34 | 34.6 | 112 | 107.2 |
| 9 | 13.4 | 5 | 5.6 | 9 | 8.8 | 23 | 27.8 | 32 | 35.2 | 23 | 25.2 | 32 | 30.0 | 87 | 90.4 |
| 9 | 10.0 | 3 | 5.0 | 8 | 7.6 | 20 | 22.6 | 26 | 28.8 | 23 | 24.8 | 33 | 26.8 | 82 | 80.4 |
| 6 | 6.4 | 5 | 4.4 | 1 | 5.0 | 12 | 15.8 | 23 | 20.6 | 21 | 21.8 | 17 | 23.0 | 61 | 65.4 |
| 6 | 5.0 | 6 | 4.0 | 7 | 3.4 | 19 | 12.4 | 17 | 15.0 | 25 | 19.0 | 18 | 19.0 | 60 | 53.0 |
| 2 | 3.0 | 3 | 3.4 | | 2.2 | 5 | 8.6 | 5 | 11.0 | 17 | 15.2 | 15 | 14.0 | 37 | 40.2 |
| 2 | 2.2 | 3 | 3.0 | 1 | 2.0 | 6 | 7.2 | 4 | 6.8 | 9 | 13.0 | 12 | 12.0 | 25 | 31.8 |
| 1 | 1.2 | | 1.8 | 2 | 0.8 | 3 | 3.8 | 6 | 4.0 | 4 | 9.0 | 8 | 9.0 | 18 | 22.0 |
| | 0.8 | 3 | 1.4 | | 1.2 | 3 | 3.4 | 2 | 3.6 | 10 | 6.4 | 7 | 7.0 | 19 | 17.0 |
| 1 | 0.4 | | 1.2 | 1 | 1.2 | 2 | 2.8 | 3 | 2.8 | 5 | 5.6 | 3 | 5.2 | 11 | 13.6 |
| | 0.6 | 1 | 1.2 | 2 | 1.0 | 3 | 2.8 | 3 | 2.0 | 4 | 5.0 | 5 | 3.8 | 12 | 10.8 |
| | 0.4 | 2 | 0.6 | 1 | 1.0 | 3 | 2.0 | | 1.6 | 5 | 3.4 | 3 | 2.6 | 8 | 7.6 |
| 2 | 0.4 | | 0.8 | 1 | 1.0 | 3 | 2.2 | 2 | 1.2 | 1 | 3.0 | 1 | 2.2 | 4 | 6.4 |
| | 0.6 | | 0.6 | | 0.8 | | 2.0 | | 0.8 | 2 | 2.2 | 1 | 1.6 | 3 | 4.6 |
| | 0.6 | 1 | 0.2 | 1 | 1.0 | 2 | 1.8 | 1 | 1.0 | 3 | 1.4 | 1 | 1.4 | 5 | 3.8 |
| 1 | 0.2 | | 0.2 | 1 | 0.8 | 2 | 1.2 | 1 | 0.6 | | 1.2 | 2 | 1.2 | 3 | 3.0 |
| | 0.2 | | 0.2 | 2 | 0.8 | 2 | 1.2 | 1 | 0.6 | 1 | 1.0 | 2 | 1.0 | 4 | 2.6 |
| | 0.2 | | | | 0.8 | | 1.0 | | 0.4 | | 0.4 | | 1.0 | | 1.8 |
| | | | | | 0.6 | | 0.6 | | 0.2 | 1 | 0.4 | | 0.6 | 1 | 1.2 |
| | | | | 1 | 0.2 | 1 | 0.2 | | | | 0.2 | 1 | 0.4 | 1 | 0.6 |
| | | | | | 0.2 | | 0.2 | | | | 0.2 | | 0.6 | | 0.8 |
| | | | | | 0.2 | | 0.2 | | | | | 1 | 0.6 | 1 | 0.6 |
| | | | | | | | | | | | 0.2 | 1 | 0.4 | 1 | 0.6 |
| | | | | | | | | | | | 0.2 | | 0.4 | | 0.6 |
| | | | | | 0.2 | | 0.2 | | | 1 | 0.4 | | 0.4 | 1 | 0.8 |
| | | | | | 0.2 | | 0.2 | | | | 0.6 | | 0.2 | | 0.8 |
| | | | | 1 | 0.2 | 1 | 0.2 | | | 1 | 0.6 | 1 | 0.2 | 2 | 0.8 |
| | | | | | 0.2 | | 0.2 | | | 1 | 0.6 | | 0.2 | 1 | 0.8 |
| | | | 0.2 | | 0.2 | | 0.4 | | | | 0.8 | | 0.4 | | 1.2 |
| | | | 0.2 | | 0.2 | | 0.4 | | | 1 | 0.6 | | 0.4 | 1 | 1.0 |
| | | 1 | 0.2 | | 0.2 | 1 | 0.4 | | | 1 | 0.4 | 1 | 0.4 | 2 | 0.8 |
| | | | 0.4 | 1 | 0.2 | 1 | 0.6 | | | | 0.6 | 1 | 0.4 | 1 | 1.0 |
| | | | 0.4 | | 0.2 | | 0.6 | | | | 0.4 | | 0.4 | | 0.8 |
| | | 1 | 0.2 | | 0.2 | 1 | 0.4 | | 0.2 | 1 | 0.2 | | 0.2 | 1 | 0.6 |
| | | | 0.2 | | | | 0.2 | | 0.2 | | 0.2 | | | | 0.4 |
| | | | 0.2 | | | | 0.2 | 1 | 0.2 | | 0.2 | | | 1 | 0.4 |
| | | | | | | | | | 0.2 | | | | | | 0.2 |
| | | | | | | | | | 0.2 | | | | | | 0.2 |

marked and those of catches. Therefore correction (*e*-correction) on number of catch and number of whales recaptured were discussed as follows. If all age groups older than one year are marked and all age groups older than four years in average are included in catchable stock, it can be assumed that all younger part of former which is smaller than

legal limit will recruit into catchable stock three years after marking. Therefore it may be mostly enough to make correction on number of catch and number of whales recaptured in one and two years after marking. $e_1e_2C'_1$, $e_1e_2R_1$ and $e_2C'_2$, $e_2R_2$ will be used in formula 5 instead

TABLE 33. NUMBER OF SURVIVOR AND DEATH OF FEMALE NUMBER OF CORPUS ALBICANS

| | Off Kamchatka (A) | | | | | | | | South of east Aleutian (B) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952~54 | | 1955~56 | | 1957~59 | | Sum | | 1954~55 | | 1956~57 | | 1958~59 | | Sum | |
| Age | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death |
| 4 | 284 | 12 | 146 | 7 | 246 | 9 | 626 | 18 | 51.8 | 2.6 | 141 | 6 | 91.5 | 4.2 | 283 | 12 |
| 5 | 272 | 13 | 139 | 5 | 237 | 8 | 608 | 23 | 49.2 | 2.4 | 135 | 5 | 87.3 | 4.1 | 271 | 12 |
| 6 | 259 | 14 | 134 | 8 | 229 | 8 | 585 | 15 | 46.8 | 2.4 | 130 | 5 | 83.2 | 4.1 | 259 | 12 |
| 7 | 245 | 22 | 126 | 7 | 221 | 7 | 570 | 16 | 44.4 | 2.0 | 125 | 5 | 79.1 | 3.1 | 247 | 12 |
| 8 | 223 | 5 | 119 | 6 | 214 | 6 | 554 | 19 | 42.4 | 2.1 | 120 | 6 | 76.0 | 3.5 | 235 | 11 |
| 9 | 218 | 14 | 113 | 4 | 208 | 6 | 535 | 23 | 40.3 | 1.9 | 114 | 6 | 72.5 | 3.0 | 224 | 11 |
| 10 | 204 | 15 | 109 | 10 | 202 | 5 | 512 | 24 | 38.4 | 2.1 | 108 | 6 | 69.5 | 4.0 | 213 | 10 |
| 11 | 189 | 16 | 99 | 7 | 197 | 5 | 488 | 26 | 36.3 | 1.9 | 102 | 6 | 65.5 | 4.3 | 203 | 13 |
| 12 | 173 | 17 | 92 | 8 | 192 | 6 | 462 | 28 | 34.4 | 2.6 | 96 | 5 | 61.2 | 6.0 | 190 | 14 |
| 13 | 156 | 19 | 84 | 7 | 186 | 7 | 434 | 30 | 31.8 | 2.7 | 91 | 6 | 55.2 | 5.5 | 176 | 15 |
| 14 | 137 | 20 | 77 | 8 | 179 | 8 | 404 | 42 | 29.1 | 3.4 | 85 | 6 | 49.7 | 4.7 | 161 | 17 |
| 15 | 117 | 24 | 69 | 9 | 171 | 9 | 362 | 48 | 25.7 | 5.5 | 79 | 8 | 45.0 | 5.0 | 144 | 17 |
| 16 | 93 | 21 | 60 | 8 | 162 | 15 | 314 | 49 | 20.2 | 6.6 | 71 | 8 | 40.0 | 4.0 | 127 | 18 |
| 17 | 72 | 18 | 52 | 8 | 147 | 28 | 265 | 57 | 13.6 | 4.2 | 63 | 9 | 36.0 | 4.0 | 109 | 17 |
| 18 | 54 | 14 | 44 | 5 | 119 | 20 | 208 | 39 | 9.4 | 1.9 | 54 | 10 | 32.0 | 3.9 | 92 | 18 |
| 19 | 40 | 9 | 39 | 6 | 99 | 15 | 169 | 27 | 7.5 | 1.3 | 43 | 12 | 28.1 | 6.4 | 74 | 17 |
| 20 | 31 | 10 | 33 | 5 | 84 | 16 | 142 | 22 | 6.2 | 0.7 | 31 | 10 | 21.7 | 6.4 | 57 | 16 |
| 21 | 21 | 4 | 28 | 6 | 68 | 12 | 120 | 19 | 5.5 | 1.0 | 21 | 4 | 15.3 | 6.1 | 41 | 11 |
| 22 | 17 | 4 | 22 | 3 | 56 | 11 | 101 | 17 | 4.5 | 0.5 | 17 | 4 | 9.2 | 4.4 | 30 | 8 |
| 23 | 13 | 2.5 | 19 | 4 | 45 | 9 | 84 | 17 | 4.0 | 0.4 | 13 | 2 | 4.8 | 2.5 | 22 | 4 |
| 24 | 10.5 | 2.0 | 15 | 3 | 36 | 9 | 67 | 14 | 3.6 | 0.3 | 11 | 1 | 2.3 | 1.5 | 18 | 3 |
| 25 | 8.5 | 2.0 | 12 | 2.5 | 27 | 6 | 53 | 20 | 3.3 | 0.5 | 10 | 1.5 | 0.8 | 0.8 | 15 | 2 |
| 26 | 6.5 | 2.0 | 9.5 | 1.5 | 21 | 6 | 33 | 11 | 2.8 | 0.3 | 8.5 | 1 | 0.0 | | 13 | 2 |
| 27 | 4.5 | 0.5 | 8 | 1.5 | 15 | 4 | 22 | 7 | 2.5 | 0.3 | 7.5 | 0.5 | | | 11 | 1 |
| 28 | 4.0 | 0.5 | 6.5 | 1.5 | 11 | 4 | 15 | 4 | 2.2 | 0.3 | 7 | 1 | | | 10 | 1 |
| 29 | 3.5 | 0.5 | 5 | 0.5 | 7 | 3 | 11 | 3 | 1.9 | 0.4 | 6 | 1 | | | 9 | 1 |
| 30 | 3.0 | 0.5 | 4.5 | 1.0 | 4 | 2 | 8 | 2 | 1.5 | 0.3 | 5 | 0.5 | | | 8 | 1 |
| 31 | 2.5 | 0.3 | 3.5 | 0.5 | 2 | 1 | 6 | 2 | 1.2 | 0.4 | 4.5 | 1 | | | 7 | 2 |
| 32 | 2.2 | 0.2 | 3 | 0.2 | 1 | 0.5 | 4 | 1 | 0.8 | 0.2 | 3.5 | 1 | | | 5 | 1.5 |
| 33 | 2.0 | 0.4 | 2.8 | 0.3 | 0.5 | 0.3 | 3 | 1 | 0.6 | 0.3 | 2.5 | 1 | | | 3.5 | 1.3 |
| 34 | 1.6 | 0.2 | 2.5 | 0.5 | 0.2 | 0.2 | 2 | 1 | 0.3 | 0.1 | 1.5 | 0.5 | | | 2.2 | 0.2 |
| 35 | 1.4 | 0.4 | 2 | 0.2 | 0.0 | | 1 | 0.5 | 0.2 | 0.2 | 1 | 0.5 | | | 2 | 1.0 |
| 36 | 1.0 | 1.0 | 1.8 | 1.8 | | | 0.5 | 0.5 | 0.0 | | 0.5 | 0.5 | | | 1 | 1.0 |
| 37 | 0.0 | | 0.0 | | | | 0.0 | | | | 0.0 | | | | 0 | |

of $C'_1$, $R_1$ and $C'_2$, $R_2$, where $e_1$ an $e_2$ can be obtained approximately as follows.

$$e_1 = \frac{1}{\text{total survival rate for age groups older than two years of the stock}},$$

$$e_2 = \frac{1}{\text{total survival rate for age groups older than three years of the stock}},$$

However, survival curve has not been obtained for these younger part of the stock from data observed. Therefore, adopting the figure of death rate of 0.025, which was estimated arbitrarily for younger age groups by Ottestad (1956), against two and three age groups, calculation

FINBACKS, ESTIMATED BY FREQUENCY DISTRIBUTION OF OF PREGNANT FEMALES

| North of east Aleutian (C) | | | | | | | | Sum of three areas | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1954~55 | | 1956~57 | | 1958~59 | | Sum | | 1952~55 | | 1956~57 | | 1958~59 | | Sum | |
| no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death | no. of survivor | no. of death |
| 536 | 43 | 278 | 27 | 212 | 14 | 1010 | 60 | 904 | 56 | 564 | 36 | 506 | 31 | 1960 | 120 |
| 493 | 45 | 251 | 28 | 198 | 16 | 950 | 90 | 848 | 64 | 528 | 40 | 475 | 27 | 1840 | 120 |
| 448 | 42 | 223 | 28 | 182 | 15 | 860 | 70 | 784 | 60 | 488 | 36 | 448 | 34 | 1720 | 120 |
| 406 | 46 | 195 | 33 | 167 | 8 | 790 | 90 | 724 | 64 | 452 | 38 | 414 | 26 | 1600 | 130 |
| 360 | 48 | 162 | 33 | 159 | 18 | 700 | 100 | 660 | 60 | 414 | 42 | 388 | 16 | 1470 | 110 |
| 312 | 46 | 129 | 26 | 141 | 13 | 600 | 90 | 600 | 56 | 372 | 37 | 372 | 11 | 1360 | 120 |
| 266 | 47 | 103 | 24 | 128 | 14 | 510 | 90 | 544 | 64 | 335 | 29 | 361 | 12 | 1240 | 100 |
| 219 | 42 | 79 | 12 | 114 | 12 | 420 | 70 | 480 | 56 | 306 | 24 | 349 | 19 | 1140 | 120 |
| 177 | 43 | 67 | 9 | 102 | 13 | 350 | 60 | 424 | 64 | 282 | 22 | 330 | 26 | 1020 | 110 |
| 134 | 36 | 58 | 7 | 89 | 14 | 290 | 60 | 360 | 68 | 260 | 22 | 304 | 34 | 910 | 110 |
| 98 | 25 | 51 | 5 | 75 | 14 | 230 | 50 | 292 | 52 | 238 | 20 | 270 | 37 | 800 | 100 |
| 73 | 18 | 46 | 5 | 61 | 16 | 180 | 40 | 240 | 56 | 218 | 20 | 233 | 28 | 700 | 100 |
| 55 | 16 | 41 | 4 | 45 | 10 | 140 | 30 | 184 | 48 | 198 | 21 | 205 | 33 | 600 | 100 |
| 39 | 11 | 37 | 5 | 35 | 9 | 110 | 20 | 136 | 37 | 177 | 21 | 172 | 30 | 500 | 90 |
| 28 | 8 | 32 | 4 | 26 | 7 | 90 | 20 | 99 | 31 | 156 | 24 | 142 | 22 | 410 | 80 |
| 20 | 7 | 28 | 5 | 19 | 3 | 70 | 20 | 68 | 20 | 132 | 22 | 120 | 20 | 330 | 70 |
| 13 | 4 | 23 | 3 | 16 | 3 | 50 | 8 | 48 | 12 | 110 | 22 | 100 | 20 | 260 | 60 |
| 9 | 2 | 20 | 4 | 13 | 1 | 42 | 4 | 36 | 8 | 88 | 18 | 80 | 17 | 200 | 40 |
| 7 | 1.5 | 16 | 3 | 12 | 1.5 | 38 | 8 | 28 | 6 | 70 | 13 | 63 | 13 | 160 | 20 |
| 5.5 | 0.5 | 13 | 2 | 10.5 | 0.5 | 30 | 2 | 22 | 2 | 57 | 10 | 50 | 12 | 140 | 30 |
| 5 | 0.5 | 11 | 3 | 10 | 0.8 | 28 | 4 | 20 | 4 | 47 | 7 | 38 | 8 | 110 | 20 |
| 4.5 | 0.5 | 8 | 1.5 | 9.2 | 0.2 | 24 | 2 | 16 | 4 | 40 | 7 | 30 | 7 | 90 | 20 |
| 4 | 0.3 | 6.5 | 1.5 | 9 | 0.0 | 22 | 2 | 12 | 1 | 33 | 6 | 23 | 5 | 70 | 10 |
| 3.7 | 0.6 | 5 | 1 | 9 | 0.0 | 20 | 1 | 11 | 3 | 27 | 4 | 18 | 2 | 60 | 10 |
| 3.1 | 0.1 | 4 | 1 | 9 | 0.0 | 19 | 2 | 8 | 1 | 23 | 5 | 16 | 2 | 50 | 10 |
| 3 | 0.2 | 3 | 1 | 9 | 0.4 | 17 | 2 | 7 | 1 | 18 | 4 | 14 | 1 | 40 | 10 |
| 2.8 | 0.3 | 2 | 0.2 | 8.6 | 0.6 | 15 | 3 | 6 | 2 | 14 | 3 | 13 | 1 | 30 | 5 |
| 2.5 | 0.3 | 1.8 | 0.4 | 8 | 0.4 | 12 | 2 | 4 | 1 | 11 | 3 | 12 | 2 | 25 | 5 |
| 2.2 | 0.2 | 1.4 | 0.4 | 7.6 | 0.6 | 10 | 1 | 3 | 1 | 8 | 2 | 10 | 1 | 20 | 5 |
| 2.0 | 0.2 | 1 | 0.5 | 7 | 1.0 | 9 | 2 | 2 | 1 | 6 | 1 | 9 | 1 | 15 | 5 |
| 1.8 | 1.8 | 0.5 | 0.5 | 6 | 1.0 | 7 | 2 | 1 | 1 | 5 | 1 | 8 | 2 | 10 | 5 |
| 0.0 | | 0.0 | | 5 | 1.0 | 5 | 2 | 0 | | 4 | 1 | 6 | 1 | 5 | 5 |
| | | | | 4 | 1.0 | 3 | 1 | | | 3 | 1 | 5 | 1 | 0 | |
| | | | | 3 | 1.0 | 2 | 1 | | | 2 | 1 | 4 | 2 | | |
| | | | | 2 | 1.0 | 1 | 1 | | | 1 | 1 | 2 | 1 | | |
| | | | | 1 | 1.0 | 0 | | | | 0 | | 1 | | | |
| | | | | 0 | | | | | | | | 0 | | | |

will be given as follows.

| Age | Number of survivor | Number of death | Death rate |
|---|---|---|---|
| 2 | $a_2$ | $a_2-a_3$ | 0.025 |
| 3 | $a_3$ | $a_3-a_4$ | 0.025 |
| 4 | $a_4$ | $a_4$ | $1-S$ |
| older than 5 | $a_5$ | | |

TABLE 34. FREQUENCY DISTRIBUTION OF NUMBER OF LAMINATION OF EAR-PLUG OF THE NORTH PACIFIC FIN WHALES, SUM OF MALES AND FEMALES TAKEN DURING FROM 1957 TO 1959

| No. of lamination of ear-plug | Off Kamchatka (A) | | South of east Aleut. (B) | | North of east Aleut. (C) | |
|---|---|---|---|---|---|---|
| | observ. | smooth. | observ. | smooth. | observ. | smooth. |
| 2～ 3 | 0 | | 0 | | 4 | |
| 4～ 5 | 14 | | 5 | | 45 | |
| 6～ 7 | 34 | | 13 | | 87 | |
| 8～ 9 | 23 | 24.6 | 15 | 16.2 | 95 | 68.6 |
| 10～ 11 | 30 | 25.0 | 23 | 18.2 | 66 | 67.2 |
| 12～ 13 | 22 | 22.2 | 25 | 19.2 | 50 | 55.2 |
| 14～ 15 | 16 | 23.4 | 15 | 18.6 | 38 | 42.8 |
| 16～ 17 | 20 | 22.0 | 18 | 17.2 | 27 | 36.2 |
| 18～ 19 | 29 | 22.4 | 12 | 16.6 | 33 | 30.6 |
| 20～ 21 | 23 | 23.2 | 16 | 16.6 | 33 | 27.2 |
| 22～ 23 | 24 | 23.6 | 22 | 15.4 | 22 | 26.8 |
| 24～ 25 | 20 | 21.0 | 15 | 15.6 | 21 | 24.0 |
| 26～ 27 | 21 | 19.8 | 12 | 13.6 | 25 | 21.0 |
| 28～ 29 | 16 | 20.2 | 13 | 12.4 | 19 | 19.0 |
| 30～ 31 | 17 | 21.4 | 6 | 11.8 | 18 | 18.0 |
| 32～ 33 | 26 | 19.0 | 16 | 11.6 | 12 | 15.0 |
| 34～ 35 | 26 | 19.2 | 12 | 10.6 | 16 | 14.6 |
| 36～ 37 | 10 | 12.6 | 11 | 11.0 | 10 | 14.2 |
| 38～ 39 | 17 | 14.4 | 8 | 9.4 | 17 | 13.6 |
| 40～ 41 | 9 | 11.6 | 8 | 8.0 | 16 | 13.0 |
| 42～ 43 | 10 | 10.8 | 8 | 7.6 | 9 | 12.2 |
| 44～ 45 | 12 | 9.6 | 5 | 5.8 | 13 | 9.8 |
| 46～ 47 | 6 | 9.4 | 4 | 4.4 | 6 | 7.4 |
| 48～ 49 | 11 | 8.8 | 3 | 3.8 | 5 | 6.4 |
| 50～ 51 | 8 | 7.6 | 2 | 3.2 | 4 | 4.8 |
| 52～ 53 | 7 | 7.0 | 5 | 3.0 | 4 | 4.4 |
| 54～ 55 | 6 | 5.2 | 2 | 3.4 | 5 | 4.0 |
| 56～ 57 | 3 | 4.0 | 3 | 3.4 | 4 | 3.4 |
| 58～ 59 | 2 | 3.4 | 5 | 2.6 | 3 | 3.8 |
| 60～ 61 | 2 | 2.8 | 2 | 2.4 | 1 | 3.0 |
| 62～ 63 | 4 | 2.4 | 1 | 1.8 | 6 | 2.6 |
| 64～ 65 | 3 | 2.6 | 1 | 0.8 | 2 | 2.6 |
| 66～ 67 | 1 | 2.4 | 0 | 0.8 | 2 | 2.8 |
| 68～ 69 | 3 | 2.2 | 0 | 0.6 | 3 | 2.4 |
| 70～ 71 | 1 | 1.8 | 2 | 0.4 | 2 | 3.0 |
| 72～ 73 | 3 | 2.6 | 0 | 0.4 | 4 | 2.8 |
| 74～ 75 | 1 | 2.6 | 0 | 0.8 | 5 | 2.6 |
| 76～ 77 | 5 | 3.2 | 0 | 0.8 | 0 | 2.4 |
| 78～ 79 | 2 | 2.8 | 2 | 0.8 | 2 | 1.8 |
| 80～ 81 | 4 | 2.8 | 2 | 1.0 | 1 | 1.2 |
| 82～ 83 | 1 | 2.0 | 0 | 1.0 | 1 | 1.2 |
| 84～ 85 | 1 | 1.6 | 1 | 0.6 | 1 | 1.0 |
| 86～ 87 | 1 | 0.8 | 0 | 0.4 | 1 | 0.8 |
| 88～ 89 | 1 | 0.8 | 0 | 0.2 | 1 | 0.8 |
| 90～ 91 | 0 | 0.6 | 1 | 0.2 | 0 | 1.0 |
| 92～ 93 | 1 | 0.6 | | 0.2 | 1 | 0.8 |
| 94～ 95 | 0 | 0.4 | | 0.2 | 2 | 0.8 |
| 96～ 97 | 1 | 0.4 | | 0.2 | 0 | 0.8 |
| 98～ 99 | 0 | 0.2 | | | 1 | 0.8 |
| 100～101 | 0 | 0.6 | | | 1 | 0.4 |
| 102～103 | 0 | 0.4 | | | | 0.4 |
| 104～105 | 2 | 0.4 | | | | 0.2 |
| 106～107 | | 0.4 | | | | 0.2 |
| 108～109 | | 0.4 | | | | 0.0 |
| 110～111 | | 0.0 | | | | |

, then

$$a_2=\frac{1-S}{S}\cdot\frac{a_5}{(0.975)^2}\,,\quad a_3=\frac{1-S}{S}\cdot\frac{a_5}{0.975}\,,\quad a_4=\frac{1-S}{S}\cdot a_5\,.$$

In consequence,

$$e_1=\frac{a_2+a_3+a_4+a_5}{a_3+a_4+a_5}=\frac{3.001-2.026\cdot S}{1.975-S}\,,\quad e_2=\frac{a_3+a_4+a_5}{a_4+a_5}=\frac{1.975-S}{0.975}\,. \tag{13}$$

Figures $e_1$ and $e_2$ will be given after adopting those of $S$ in Table 35 to formula 13. As in this case figures of $S$ in any areas A, B and C give approximately same results to $u$ in formula 5, averaged value by area around Aleutians was used. In consequence figures of $e_1e_2=1.4$,

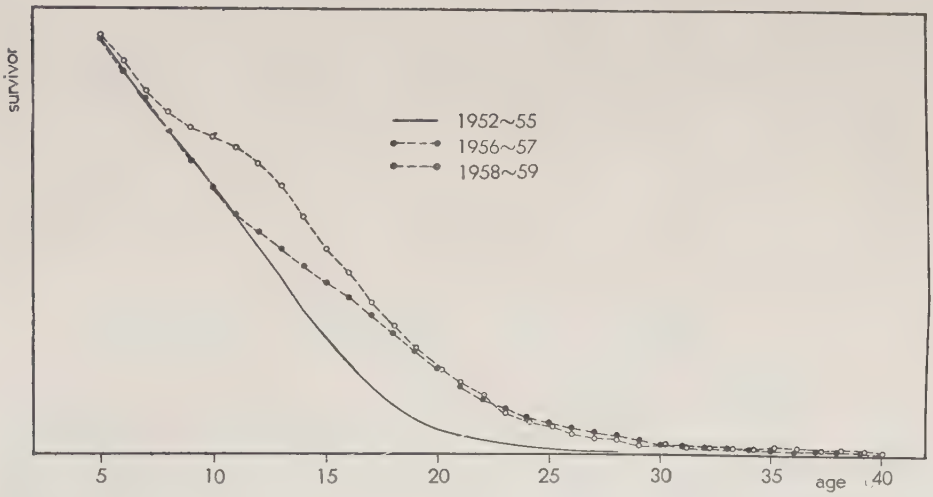



Fig.5. Age composition of the North Pacific Fin whales, estimated from distribution of frequency of corpus ablicans of pregnant females.

TABLE 35. SURVIVAL RATES (S) OF THE NORTH PACIFIC FINBACKS

| | | Off Kamchatka (A) | East Aleutian south (B) | East Aleutian north (C) | Whole area |
|---|---|---|---|---|---|
| I | Season 1 | .8261 | .8386 | .7505 | .7914 |
| | Season 2 | .8490 | .8562 | .7496 | .8248 |
| | Season 3 | .8729 | .8609 | .8075 | .8440 |
| | Average | .8573* | .8481 | .7589* | .8192 |
| II | Season 1 | .9010 | .9079 | .8564 | .8783 |
| | Season 2 | .9131 | .9175 | .8534 | .9008 |
| | Season 3 | .9274 | .9108 | .8891 | .9095 |
| | Average | .9194* | .9133 | .8714* | .8962 |
| III | | .9397 | .9140 | .8730 | — |

Figures in columns I and II are calculated from freq. distribution of no. of corpus albicans of pregnant females as the average number of ovulation of 2.8 or 1.6 in one breeding season. Figures in column III are calculated from freq. distribution of no. of lamination of ear-plug.

Seasons 1, 2 and 3 correspond to three periods of 1952~54, 1955~56, and 1957~59 in area A, those of 1954~55, 1956~57, and 1958~59 in areas B and C and those of 1952~55, 1956~57, and 1958~59 in whole area.

* These figures are used for calculation in formula 12 as survival rate (S).

$e_2=1.2$ and $e_1e_2=1.2$, $e_2=1.1$ were obtained against two cases of averaged number of ovulation 2.8 and 1.6 respectively. Thus various coefficients necessary for calculation of formulas 5 and 6 were obtained.

It should be discussed here that whether marked whales show random distribution in the stock, to which they belong, or not in various areas. For this purpose whether rate of recapture of marked whales fluctuate little or not from year to year were examined firstly on the data on 206 whales which were recorded as ' Hit ' in area C in 1954. Table 36 shows

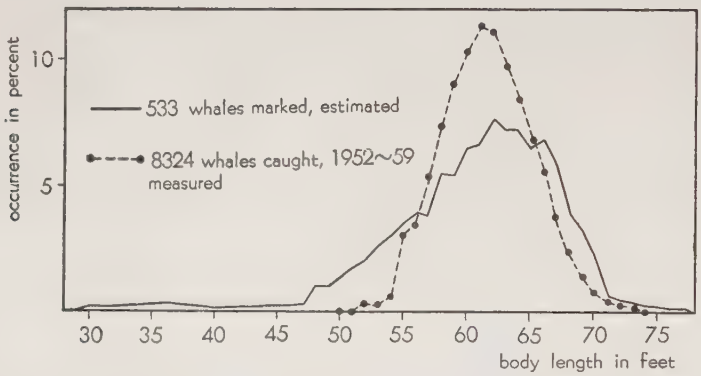



Fig. 6. Comparison of size distributions of whales caught (measured) and marked (estimated).

number of whales recaptured, number of catch and rate of recapture calculated from formula 5 for five years during from one year (1955) and five years (1959) after marking. But no $1/f$ correction is made in those calculations. It can be seen from this table that yearly fluctuations of rate of recapture are very small as shown by figures of $u=0.007300\pm 0.000455$ and $0.005950\pm 0.000465$ against two cases of averaged number of ovulation 2.8 and 1.6. Number of whales recaptured from 1000 whales of annual catch are given by formula 14. $y$ means number of whales recaptured in each year, and $Y$ means total number of those, and I II correspond to two cases of averaged number of ovulation 2.8 and 1.6.

$$\left.\begin{aligned} y&=7.30\times 0.7589^x \\ Y&=22.98(1-0.7589^x)\end{aligned}\right\}\ \mathrm{I} \qquad \left.\begin{aligned} y&=5.95\times 0.8714^x \\ Y&=40.32(1-0.8714^x)\end{aligned}\right\}\ \mathrm{II} \qquad (14)^*$$

* These formulas are given in general as follows.

$$y=1000u\cdot S^x$$

, and

$$Y=1000(u\cdot S+u\cdot S^2+u\cdot S^3+\cdots+u\cdot S^x)=1000\frac{u\cdot S}{1-S}(1-S^x) \qquad (15)$$

, where $S$ means survival rate and $u$ means rate of recapture of marked whales against annual catch. If marked whales distribute at random in the stock to which they belong,

$$u=T/N \qquad (16)$$

, where $T$ is number of whales marked effectively and $N$ means stock number.

Calculated figures of $y$ and $Y$ are shown in Table 37 and Fig. 7. In this table observed values are obtained from Table 36 directly and expected those are obtained from formula 14. Figure 7 shows that number of whales recaptured in each year fluctuate along expected curve, but that observed values in total number of those are highly consistent with expected values in general. Curve $Y$ in averaged number of ovulation 2.8, however, seem to have too low values in five (and may be also in successive) years after making, and this should be discussed

TABLE 36. ANNUAL RECAPTURE FROM 206 WHALES MARKED IN THE AREA OF NORTH OF EAST ALEUTIAN (C) IN 1954

| | Year | $x$ | $R_x$ obs. | $R_x$ cor.[d] | $C_x$ obs. | $C_x$ cor.[d] | $S$[c] | $C_x'$ | $\Sigma R_x$ | $\Sigma C_x'$ | $\Sigma R_x/\Sigma C_x'$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I[a] | 1955 | 1 | 7 | 9.8 | 1177 | 1648 | .7589 | 1251 | 9.8 | 1251 | .007834 | * |
| | 56 | 2 | 2 | 2.4 | 774 | 929 | .5759 | 535 | 12.2 | 1786 | .006831 | |
| | 57 | 3 | 1 | 1 | 286 | 286 | .4371 | 125 | 13.2 | 1911 | .006907 | |
| | 58 | 4 | 1 | 1 | 298 | 298 | .3317 | 99 | 14.2 | 2010 | .007065 | |
| | 59 | 5 | 3 | 3 | 703 | 703 | .2517 | 177 | 17.2 | 2187 | .007865 | |
| II[b] | 1955 | 1 | 7 | 8.4 | 1177 | 1412 | .8714 | 1230 | 8.4 | 1230 | .006829 | ** |
| | 56 | 2 | 2 | 2.2 | 774 | 851 | .7593 | 646 | 10.6 | 1876 | .005650 | |
| | 57 | 3 | 1 | 1 | 286 | 286 | .6617 | 189 | 11.6 | 2065 | .005617 | |
| | 58 | 4 | 1 | 1 | 298 | 298 | .5766 | 172 | 12.6 | 2237 | .005633 | |
| | 59 | 5 | 3 | 3 | 703 | 703 | .5024 | 353 | 15.6 | 2590 | .006023 | |

Means & stand. deviat., * .007300±.000455, ** .005950±.000465.

a), b) In columns I and II, figures for correction of $R_x$, $C_x$ and survival rate $S$ used correspond to those in two cases that average no. of ovulation in a breeding season is 2.8 and 1.6 respectively, that is, survival rate $S=0.7589$, $e_1e_2=1.4$ and $e_2=1.2$ for the former and $S=0.8714$, $e_1e_2=1.2$ and $e_2=1.1$ for the latter.

with additional data hereafter. Thus, following conclusion can be introduced. Whales in area C in the year 1954, distribute uniformly in the stock which migrate to the same area in successive years after marking. Gradual decrease in number of whales recaptured in successive years are caused by dilution of original stock in the year of marking with approximately constant rate of annual recruit from younger generation of the stock, and dilution of stock by mingling with different populations could be hardly supposed.

Table 38 shows rates of recapture against one thousand whales of annual catch on whales marked in the years besides 1954. It can be seen from this table that rate of recapture for years 1954, 55 and 56 are well consistent with each other. But figure for year 1958 is two times of the former and figure for year 1957 is very high. As $r_2^2$ is obtained finally as averaged value of $u$ with weight, it is little effected by figure for the year 1958, but is remarkably effected by figure for the year 1957. Detailed records on marking and recovery of whales marked in this year are shown in Table 39. According to this table, six whales (dart nos. J6815, J6801, J6802, J6837, J6829,

J6843) out of those marked in neighbouring area each other for several days in this year are taken in neighbouring area again in the year 1958, and this fact cause to make rate of recapture remarkably high. Therefore, it is more appropriate to remove data on whales marked in 1957 from calculation of $r_2^2$ and $r_1^2$ through formula 6. Results of actual calculation will be described later.

TABLE 37. NUMBER OF RECAPTURE FROM 1000 WHALES OF ANNUAL CATCH

| Year | Years after marking, $x$ | No. of annual recept., $y$ | | | Sum. of recapt., $Y$ | | |
|---|---|---|---|---|---|---|---|
| | | observ. | expect. | | observ. | expect. | |
| | | | I | II | | I | II |
| 1955 | 1 | 5.9 | 5.5 | 5.2 | 5.9 | 5.5 | 5.2 |
| 56 | 2 | 2.6 | 4.2 | 4.5 | 8.5 | 9.7 | 9.7 |
| 57 | 3 | 3.5 | 3.2 | 3.9 | 12.0 | 12.9 | 13.6 |
| 58 | 4 | 3.4 | 2.4 | 3.4 | 15.4 | 15.3 | 17.0 |
| 59 | 5 | 4.3 | 1.8 | 3.0 | 19.7 | 17.1 | 20.0 |

On the other hand rate of recapture of whales marked in area A show remarkable annual fluctuations. This seems to be caused by not only scantiness of number of whales marked but also non-random distribution of marked whales in the stocks which migrate to this area from year to year ; in other words, migratory ranges of different populations cover this area. Practically, however, various causes and mechanisms

TABLE 38. RATE OF RECAPTUER OF WHALES MARKED AND RECAPTURED IN THE AREA OF NORTH OF EAST ALEUTIAN FROM 1000 WHALES OF ANNUAL CATCH[a)]

| Year, marked | $x$ | $u_x$ | $T_x-R_x'$ | $u_x/T_x-R_x'$ | Weight | Average value with weight | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | not exclude 1957 & 58 | exclude 1957 | exclude 1957 & 58 |
| 1954 | 1 | 5.947 | 243.08 | .02447 | 5 | | | |
| 55 | 2 | 1.003 | 35.88 | .02795 | 4 | | | |
| 56 | 3 | 2.018 | 71.25 | .02832 | 3 | .08699 | .02836 | .02659 |
| 57 | 4 | 17.379 | 37.13 | .46806 | 2 | | | |
| 58 | 5 | 1.633 | 32.94 | .04957 | 1 | | | |

a) Figure corrected for $f$ and $g$ and calculated for average number of ovulation 1.6.

of yearly fluctuations can not be analysed in detail as undertaken on those in area C because of scantiness of data, so that $r_1^1$ and $r_2^1$ were calculated from figures of $u$ in each year through formula 6.

Calculated results of rate of recapture of whales marked in areas A, B and C are shown in Tables 40, 41 and 42. Table 40 shows comparison by two cases of averaged number of ovulation 1.6 and 2.8 in a breeding season which were adopted for calculation of survival rate from frequency distribution of number of corpus albicans of pregnant whales. It can be seen from this table that individual values of rate of recapture in case

of averaged number of ovulation 2.8 are somewhat higher than those in another case, but there is little difference in their relative values. Table 41 show comparison by two cases before and after $1/g$ and $1/f$ corrections. It may be seen in this comparison also that despite of

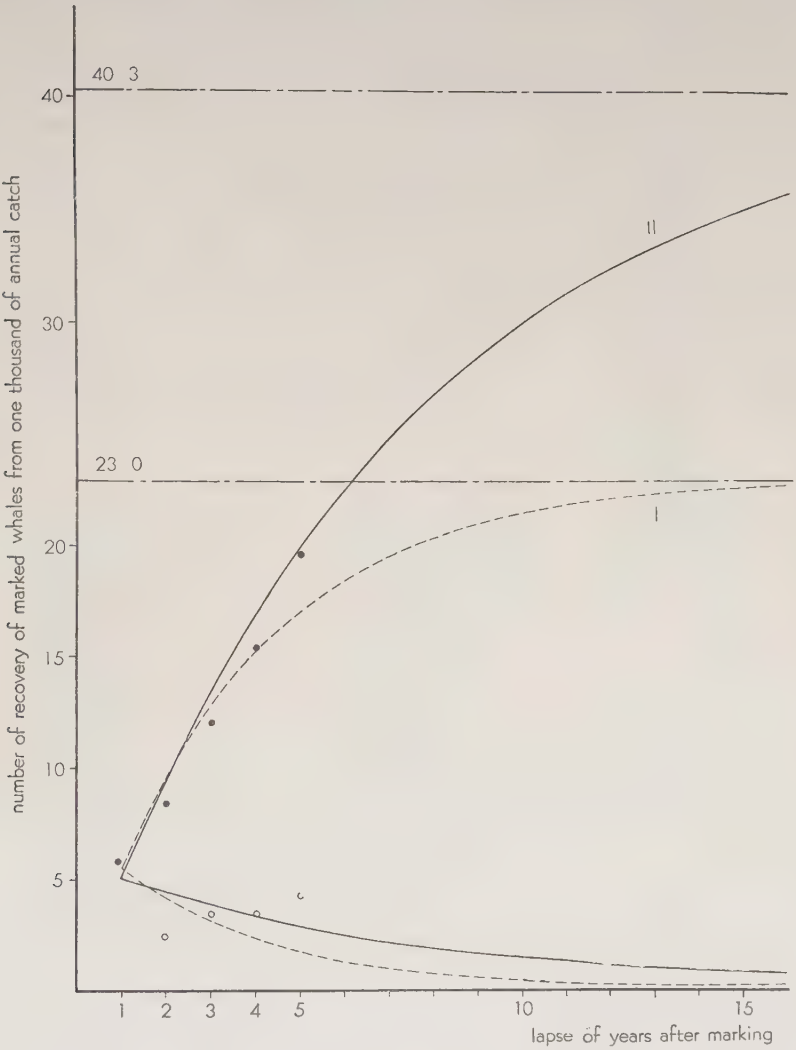



Fig 7. Annual recovery of whales marked in 1954 (206 whales marked) in the area C, north of east Aleutian, showing two cases I and II against survival rates of 0.7589 and 0.8714 respectively.

tolerable difference in individual values of rate of recapture, there is little difference in relative values. According to above-stated facts it can be concluded that errors in estimated values of averaged number of ovulation, $g$ and $f$ hardly effect on the results of rates of emigration.

In Tables 40 and 41 localities of recapture of two whales out of those marked in area B are indefinite, because their markers were recovered from oil-cooker or oil-separator of factory ship after treatment of whale

TABLE 39. REMARKS ON WHALES MARKED IN THE AREA OF NORTH OF EAST ALEUTIAN IN 1957 AND RECAPTURED IN SUCCESSIVE YEARS

| , marked | | | | , recaptured | | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Locality | No. of whales[1] | No. of whales | Dart no. | Date | Locality | Area[2] |
| June 10, 1957 | 55N 168~9W | 4 | 1 | 7269 | June~July, 1957 | NI[3] | B or C[6] |
| 〃 11, 〃 | 54N 168W | 1 | 1 | 7263 | July 30, 1959 | 53N 168~169W | C[7] |
| 〃 25, 〃 | 54N 170W | 2 | | | | | |
| 〃 29, 〃 | 55N 168W | 2 | | | | | |
| July 6, 〃 | 56N 170W | 1 | 1 | J 6506 | Aug. 11, 1957 | 63N 178W | off Navarin[8] |
| Sept. 7, 〃 | 54N 167W | 2 | 1 | J 6788[4] | June 30, 1959 | 53N 177~178W | C |
| 〃 8, 〃 | 54N 168W | 3 | | | | | |
| 〃 9, 〃 | 54N 169W | 2 | | | | | |
| 〃 10, 〃 | 54N 168W | 6 | 4 | * J 6815 | July 4, 1958 | 54N 170W | C |
| | | | | * J 6801 | 〃 11, 〃 | 54N 169W | C |
| | | | | * J 6802 | 〃 11, 〃 | 54N 169W | C |
| | | | | J 6799 | 〃 16, 〃 | 50N 170W | B |
| 〃 11, 〃 | 54N 167W | 10 | 5 | * J 6837[5] ( J 6831) | 〃 3, 〃 | 53N 169W | C |
| | | | | * J 6829 | 〃 8, 〃 | 54N 166W | C |
| | | | | * J 6843 | 〃 8, 〃 | 54N 166W | C |
| | | | | J 6807 | 〃 9, 1959 | 53N 169W | C |
| | | | | J 6834 | May 27, 1958 | 52N 171E | A |

1) number of whales recorded as 'Hit' only when marked, 2) areas temporarily classified as A (off Kamchatka), B (south of east Aleutian) and C (north of east Aleutian), 3) NI, no detailed information obtained, 4) recovered from whales recorded as 'Possible hit' when marked, 5) two markers in one whale, 6) recovered from cooker, 7) 8) recovered from refrigerated ship.

body. One was marked in area B (54°42′ N, 159°25′ W) in July 18, 1956 (marker number J6149) and was recaptured in area B or C during from June 29 to July 11, 1958. Another was marked in area B (50° 37′ N, 168°33′ W) in June 17, 1958 (marker number 6860) but locality

of recapture is indefinite because its marker was recovered from oil-separator Aug. 17, 1959. Therefore, as shown in Tables 40 and 41 rate of recapture are calculated against four cases of combination which each of these two whales is recaptured in area B or C. As rate of recapture show remarkable difference by case, rate of emigration from areas B to C is not able to be discussed quantitatively so far. Rate of emigration from areas B to C, however, show tolerably high value in all four cases, so that it is obvious that whales migrate to area B are closely related to those migrate to area C and it is difficult at present to suppose existence of the third different populations migrate to the middle area besides east (II) and west (I) populations.

TABLE 40. COMPARISON OF RATES OF RECAPTURE OF MARKED WHALES PER 1000 OF ANNUAL CATCH BY CASE OF AVERAGE NUMBER OF OVULATION 1.6 OR 2.8[1]

| | | for no. of ovul. 1.6: recaptured from area of | | | for no. of ovul. 2.8: recaptured from area of | | |
|---|---|---|---|---|---|---|---|
| | | Kamchatka | s. of e. Aleut. | n. of e. Aleut. | Kamchatka | s. of e. Aleut. | n. of e. Aleut. |
| Marked in area of | Kamchatka | .13541 | .00000 | .00307 | .16106 | .00000 | .00426 |
| | south of east Aleut. [2] | .00000 | .18125 | .05371 | .00000 | .19465 | .07374 |
| | [3] | | .00753 | .06742 | | .00807 | .08948 |
| | [4] | | .17372 | .06402 | | .18658 | .08648 |
| | | | .00000 | .07773 | | .00000 | .10222 |
| | n. of e. Aleut. | .02404 | .02208 | .08699 | .02663 | .02797 | .10392 |
| $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1}$ | | | .978 : .022 | | | .974 : .026 | |
| $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ | | | .217 : .783 | | | .204 : .796 | |

1) f, g corrected.

2) Figures in columns 1, 2, 3 and 4 show those for four cases in which two whales recaptured from B, B and C, C and B and C areas respectively.

In Table 29 whaling grounds in the northern part of north Pacific are temporarily divided into four areas. Among these, however, area off Navarin and Pribilof is closely related to area of north of east Aleutian (c) as shown by results of emigration of whales in the year of marking, so that rates of recapture are calculated for two cases in which Navarin-Pribilof area is put together to area C or not. Little difference in rate of emigration was seen between two cases. Then figurse of $r_1^1$, $r_2^1$, $r_1^2$ and $r_2^2$ and rates of emigration $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1}$ and $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ were calculated for two cases including data on whales marked in area C in 1957 or not. Though significant differences are seen between these two cases, but the latter figures were used for the successive calculations

because of the reasons noted already (p. 123, l. 21–24). Figures of rate of emigration from areas A to C, 0.978 : 0.022 in table 42 show that west sides' population hardly migrate to area C. This fact confirm the existence of west and east sides' populations which was clarified by blood typing investigations already. In following paragraph gene frequencies and relative sizes of populations I and II will be calculated from rates of emigration and gene frequencies in various areas through formula 4, and averaged ratios of mingling of populations I and II in areas A, B and C will be given.

TABLE 41. COMPARISON OF RATE OF RECAPTURE OF MARKED WHALES PER 1000 OF ANNUAL CATCH BEFORE AND AFTER f AND g CORRECTIONS[1]

| | | not corrected for f and g recaptured from area of | | | corrected for f and g recaptured from area of | | |
|---|---|---|---|---|---|---|---|
| | | Kamchatka | s. of e. Aleut. | n. of e. Aleut. | Kamchatka | s. of e. Aleut. | n. of e. Aleut. |
| Marked in area of | Kamchatka | .07617 | .00000 | .00384 | .13541 | .00000 | .00307 |
| | south of east Aleut. 1[2] | .00000 | .20646 | .06468 | .00000 | .18125 | .05371 |
| | 2 | | .00941 | .08023 | | .00753 | .06742 |
| | 3 | | .19704 | .07757 | | .17372 | .06402 |
| | 4 | | .00000 | .09312 | | .00000 | .07773 |
| | n. of e. Aleut. | .02744 | .03151 | .10473 | .02404 | .02208 | .08699 |
| $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1}$ | | | .952 : .048 | | | .978 : .022 | |
| $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ | | | .208 : .792 | | | .217 : .783 | |

1) Figures calculated for average number of ovulation 1.6 per breeding season.
2) Figures in columns 1, 2, 3 and 4 correspond to those in previous table.

B. Estimation of ratios of mingling of populations I and II by means of rates of recapture of marked whales and blood type gene frequencies. As stated already, various figures in Table 42 were calculated, for convenience, under hypothesis that marking in areas A and C were carried out against unmingled populations I and II respectively. But actually whales in areas A and C should be regarded as mingled those of populations I and II. Therefore figures of right and left terms in ratio of $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1}$ show upper and lower limits in probable values respectively, and figures of left and right terms in ratio of $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ show upper and lower limits respectively. Ratio of $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1} = .978 : .022$ in Table 42 may be substituted by 1.000 : .000 without giving significant difference to final results of rates of emigration.

TABLE 42. COMPARISON OF RATES OF RECAPTURE BETWEEN TWO CASES IN WHICH RECAPTURES FROM WHALES, MARKED IN THE AREA OF NORTH OF EAST ALEUTIAN IN 1957, ARE EXCLUDED OR NOT[1]

| | Recapture from whales marked in 1957 are | | | |
|---|---|---|---|---|
| | included recapt. from area of | | not included recapt. from area of | |
| | Kamchatka | north of e. Aleut. | Kamchatka | north of e. Aleut. |
| Marked in area of Kamchatka | .13541 | .00307 | .13541 | .00307 |
| Marked in area of n. of e. Aleut. | .02404 | .08699 | .01673 | .02836 |
| $\frac{r_1^1}{r_1^1+r_2^1} : \frac{r_2^1}{r_1^1+r_2^1}$ | .978 : .022 | | .978 : .022 | |
| $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ | .217 : .783 | | .371 : .629 | |

1) Figures corrected for f and g, and calculated for average number of ovulation 1.6 per breeding season.

On the other hand intact figure of $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ can be used, because population I hardly migrates to area C. Schematic relationships of mingling of populations I and II in areas A and C may be shown as Fig. 8. Gene frequencies in both three allele A and B systems were adopted to calculations. Relationships stated above will be formulated as follows.

In area A

$$\left.\begin{aligned} p_A &= \frac{r_1^1}{r_1^1+r_2^1}N_1p_1 + \frac{r_1^2}{r_1^2+r_2^2}N_2p_2 \\ q_A &= \frac{r_1^1}{r_1^1+r_2^1}N_1q_1 + \frac{r_1^2}{r_1^2+r_2^2}N_2q_2 \\ r_A &= \frac{r_1^1}{r_1^1+r_2^1}N_1r_1 + \frac{r_1^2}{r_1^2+r_2^2}N_2r_2 \end{aligned}\right\}$$

, and in area C

$$\left.\begin{aligned} p_C &= \frac{r_2^1}{r_1^1+r_2^1}N_1p_1 + \frac{r_2^2}{r_1^2+r_2^2}N_2p_2 \\ q_C &= \frac{r_2^1}{r_1^1+r_2^1}N_1q_1 + \frac{r_2^2}{r_1^2+r_2^2}N_2q_2 \\ r_C &= \frac{r_2^1}{r_1^1+r_2^1}N_1r_1 + \frac{r_2^2}{r_1^2+r_2^2}N_2r_2 \end{aligned}\right\} \quad (16)$$

, where $N_1$ and $N_2$ are averaged relative sizes of populations I and II which actually migrate to areas A and C, $p_1\ q_1\ r_1$, $p_2\ q_2\ r_2$, $p_A\ q_A\ r_A$ and $p_C\ q_C\ r_C$ are blood type gene frequencies of populations I and II and those of areas A and C respectively. Results of various figures on populations I

and II calculated from this formula and figures in Tables 13 and 42 are shown in Table 43. It is obvious from Table 43 that there is no difference in gene frequencies of population II between two cases including marking data in 1957 or not, but that there is some difference in those of population I. Moreover relative sizes of populations I and II show

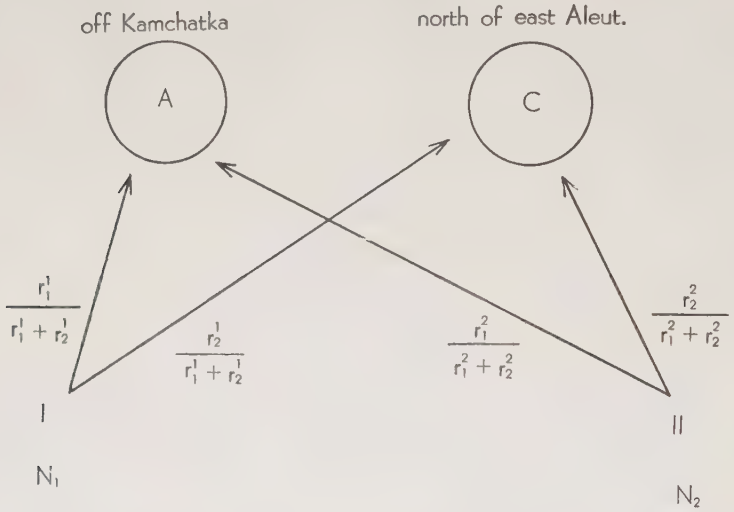



Fig. 8. Diagramatic correlation between west (I) and east (II) populations estimated from the movements of marked whales. $N_1$ and $N_2$ mean relative size of each population actually migrate to areas A and C.

TABLE 43. GENE FREQUENCIES OF Ju BLOOD GROUPS AND RELATIVE STOCK NUMBER OF POPULATIONS I AND II

| | | Include recapture from whales marked in 1957 | | Exclude recapture from whales marked in 1957 | |
|---|---|---|---|---|---|
| | | popul. I | popul. II | popul. I | popul. II |
| A system | $p$ | .075 | .026 | .112 | .026 |
| | $q$ | .500 | .869 | .222 | .869 |
| | $r$ | .425 | .105 | .666 | .105 |
| B system | $p$ | .575 | .896 | .334 | .896 |
| | $q$ | .043 | .002 | .074 | .002 |
| | $r$ | .382 | .102 | .592 | .102 |
| Relative stock number | | .74 | 1.26 | .43 | 1.57 |

differences between both cases, and $N_2$ is always larger than $N_1$ as shown by $N_2/N_1=1.7$ or 3.7. Ratios of mingling of populations I and II in areas A and C are calculated from figures of $N_1$ and $N_2$ and those in Table 43 through formula 4 and mingling rate in area B is calculated from gene frequencies of populations I and II (Table 42). These results are shown in Tables 44 and 45. It can be seen from the latter table that the results show remarkable difference by allele systems A or B.

Ratios of mingling $b$ and $1-b$ in three alleles does not proportionate each other in A system, but approximately proportionate in B system. These facts were confirmed with chi-square tests of observed values against expected those in frequency of occurrence of phenotypes. Possibility of mingling shown in Table 44 is denied in A system but is affirmed in

TABLE 44. RATIO OF MINGLING OF POPULATIONS I AND II IN THE AREAS OFF KAMCHATKA, SOUTH AND NORTH OF EAST ALEUTIAN

| | | Kamchatka | S. of e. Aleut. | | North of east Aleut. |
|---|---|---|---|---|---|
| | | | A system | B system | |
| Include recapture from whales marked in 1957 | popul. I | .73 | .51 | .29 | .02 |
| | popul. II | .27 | .49 | .71 | .98 |
| Exclude recapture from whales marked in 1957 | popul. I | .42 | .29 | .10 | .01 |
| | popul. II | .58 | .71 | .90 | .99 |

TABLE 45. COMPARISON BETWEEN OBSERVED VALUE AND EXPECTED VALUE OF BLOOD GROUP GENE FREQUENCIES IN THE AREA OF SOUTH OF EAST ALEUTIAN

| Allele system | | | Gene frequency | | Ratio of mingl.[1] | |
|---|---|---|---|---|---|---|
| | | | obs. | exp.[2] | $b$ | $1-b$ |
| Include recapture from whales marked in 1957 | A | $p$ | .071 | .051 | .92 | .08 |
| | | $q$ | .739 | .681 | .35 | .65 |
| | | $r$ | .190 | .268 | .27 | .73 |
| | | | | average | .51 | .49 |
| | B | $p$ | .810 | .803 | .27 | .73 |
| | | $q$ | .017 | .014 | .36 | .64 |
| | | $r$ | .173 | .183 | .25 | .75 |
| | | | | average | .29 | .71 |
| Exclude recapture from whales marked in 1957 | A | $p$ | .071 | .051 | .52 | .48 |
| | | $q$ | .739 | .681 | .20 | .80 |
| | | $r$ | .190 | .268 | .15 | .85 |
| | | | | average | .29 | .71 |
| | B | $p$ | .810 | .818 | .11 | .89 |
| | | $q$ | .017 | .024 | .07 | .93 |
| | | $r$ | .173 | .158 | .13 | .87 |
| | | | | average | .10 | .90 |

1) ratio of mingling of populations I and II.

2) calculated from gene frequencies of populations I and II and averaged ratio of mingling.

B system. This fact confirm that B allele system can better interpret the results observed than A system as assumed already by quantitative comparisons of blood type gene frequencies only. But additional basic discussions on phenotype-genotype relationships should be undertaken hereafter before reaching definite conclusions on allele system. In present paper, for convenience, three allele B system and rates of emigration excluding marking data in 1957 are adopted finally. Then ratio of mingling in area B is obtained as $m_{\mathrm{I}:\mathrm{II}}^{\mathrm{B}} = .10 : .90$. According to the results discussed above, it can be concluded that population I migrate to areas A and B but does hardly to area C, and population II migrate not only to area C but also to areas B and A, that is, migratory ranges of

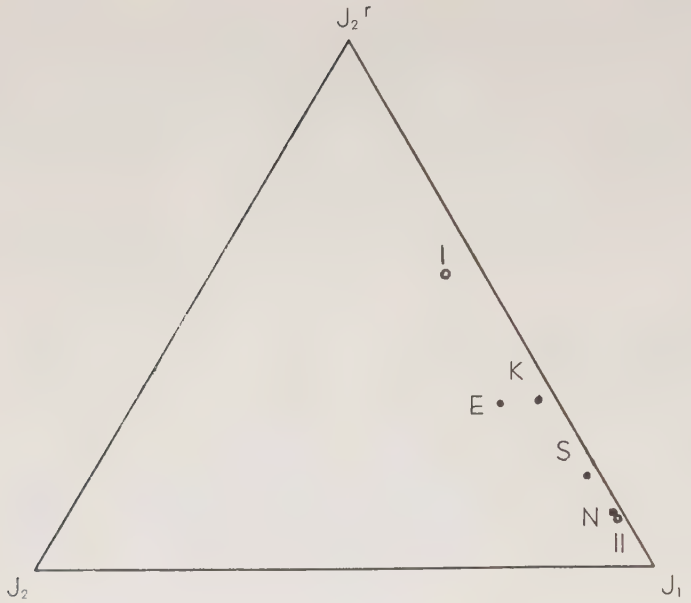



Fig. 9. Relative positions of the local populations of the North Pacific Finback whales in the triangular coordinates, expressed through the three allele B system of Ju blood group.

E: East China Sea
K: Kamchatka
I: Population I
S: South of east Aleut. (observed)
N: North of east Aleut.
II: Population II

TABLE 46. SUMMARY OF VARIOUS FIGURES DISCUSSED IN THIS SECTION

a) Blood group gene frequencies[1]

| | | Population I | Kamchatka | South of east Aleut. obs. | South of east Aleut. exp.[2] | North of east Aleut. | Population II |
|---|---|---|---|---|---|---|---|
| Gene freq. | $p$ | .334 | .662 | .810 | .818 | .890 | .896 |
| | $q$ | .074 | .032 | .017 | .024 | .003 | .002 |
| | $r$ | .592 | .306 | .173 | .158 | .107 | .102 |
| Freq. of phenotypes | $[Ju_1]$ | .503 | .844 | .937 | .928 | .982 | .985 |
| | $[Ju_1Ju_2]$ | .053 | .042 | .027 | .039 | .006 | .004 |
| | $[Ju_2]$ | .444 | .114 | .036 | .033 | .012 | .011 |

[1] in three allele B system only, 2) calculated from ratio of mingling.

b) Averaged ratio of mingling between populations I and II:

| | | Area: Kamchatka | South of east Aleut. | North of east Aleut. |
|---|---|---|---|---|
| Population | I | .42 | .10 | .01 |
| | II | .58 | .90 | .99 |

c) Relative stock number of populations I and II actually migrate to the areas off Kamchatka and north of east Aleutian:

$N_1 = 0.43$ $N_2 = 1.57$

populations I and II overlap in areas A and B. Relative size of both populations which actually migrate to area A fluctuate from year to year, and gene frequencies observed in area A fluctuate correspondingly. As blood typing data, however, have not been obtained during full period for marking investigation, there are assumed to be some bias in observed values of gene frequency of population I, because they were obtained as averaged figure by year. On the other hand, gene frequency of population II is not affected by this and seems to include little bias. Even if there is some bias in gene frequencies of population I, these figures will be available for discussing yearly fluctuation of ratio of mingling between both populations in various areas. For this purpose additional number of whales should be observed hereafter. Summarized results of various figures in this paragraph are shown in Table 46.

## DISCUSSION AND SUMMARY

In the present paper after analysing sub-populations of the north Pacific finback whales, the author clarified that two different populations, which their migratory ranges overlap each other in feeding season, distribute in areas around Aleutian Chains, and that whales taken from East China Sea belong to a different local population which is isolated from above those. Various assumptions were rendered during these analysis, so that it should be discussed here that how do they effect upon final conclusions in the present report.

*Problems in immunogenetics.* Despite of somewhat lower precision in blood typing Bp antigen, the facts that $Bp_1$ antigen occurs in area off Kamchatka (A) and while does not in area of north of east Aleutian (C) are sufficient evidence to show existence of local populations in these two areas. On the other hand, it can be supposed that misclassification of Ju blood types hardly has happened, because of obverse and reverse correlations between $Ju_1$ and $Ju_2$ antigens, dosage effect between homozygous and heterozygous types and purification of standard reagents. Moreover, as specific agglutinin has sufficient high titer even after dilution with saline for actual use, it can be hardy assumed that weaker heterozyous type was misclassified as homozygous type $Ju_1$. As regards allele system of Ju blood type, after discussing discrepancies from Hardy-Weinberg's Equilibrium in frequency of occurrence of phenotypes and parentages between cows and fetuses, two allele system is denied and then at least three alleles should be supposed. Then problems of identification and mingling of populations were investigated through two kinds of hypothetical three allele systems A and B. It was discussed whether continued ratios of gene frequencies between neighbouring three areas

reveal approximately same figures in three alleles each other or not. Consequently it was clarified from discussions through both allele systems A and B that whales taken from East China Sea belong to a local population isolated from those around Aleutians. As regards correlations between three areas off Kamchatka (A), south of east Aleutian (B), and north of east Aleutian (C), after above-stated discussion it was denied through A system that populations from both side's areas mingle in middle area but it was affirmed through B system. On the other hand, as emigration of marked whales between both side's areas, have been reported it is not probable that mingling in middle area is completely denied, so that A allele system seems to give results contradictory to the facts observed. In other words, though direct evidences have not been obtained yet, B allele system could better interpret the facts of observation than A system at present. As revealed by the rate of emigration of marked whales, populations in the areas A and B are mirgled those of populations I and II. But results of discussions on figures in Table 27 and successive those, which were calculated through formulas 2 and 3, can lead to final conclusions in the present paper.

According to the phenomena of dosage effect in Ju heterozygous types, additional alleles related to possible sub-types can be supposed, but available data are too scanty to discuss this problem definitely. Existence of this new fourth allele, however, might not effect upon analysing results of racial study basing on three allele systems.

*Effects of estimation of various figures in calculation of ratio of mingling and some biological factors to the results discussed in the present paper.* To calculate rate of emigration, it was presumed for convenience that marking in areas A and C were performed against unmingled populations I and II. As population II, however, actually migrate to area A, rate of emigration of population II to this area is obtained as a upper limit averaged for period of investigations. According to same thinking it can be thought that major part of population I distribute to area A and a part to area B, but it scarecely migrate to area C. This fact is confirmed by the blood typing evidences that $Bp_1$ antigen occurs in area A but does not in area C at all.

Effects of errors in estimates of $f$, $g$, $e_1$, $e_2$ and $S$ in formulas 5 and 6 to ratios of mingling and other final results in present report will be discussed here. At first $g$ means rate of confirming number of whales hit, against those effectively marked and was given as rate of number of whales recaptured from those recorded as 'hit' when marked against total number of recapture. Coefficient $f$ means rate of recovery of marker from whales recaptured, and was estimated experimentally.

Actually one whale is shot by two or more darts in low frequency, so that it could be approved that rate of recovery of marker $f$ is equal to rate of confirming recaptured whales. As stated in discussions on Table 41, figures $f$ and $g$ thus obtained fairly effect upon values of $r_1^1$, $r_2^1$, $r_1^2$ and $r_2^2$, but hardly do to rates of emigration calculated as relative value of these. Figures of $e_1$, $e_2$ and $S$ were calculated for two cases assuming average number of ovualation per breeding season 2.8 or 1.6. Errors of estimate of $e_1$ and $e_2$ effect upon only first and second terms of numerator and denominator in formulas 5 and 6. As regards estimate of survival rates $S$ matters are as follows. For example populations I and II migrate to area A and some geographical segregation by age in a population may be supposed. As being obvious from formula 12, however, errors of survival rate $S$ estimated from ovarian data of catch in each area effects a little upon only first term and hardly upon second term and after as negligible minute more than two orders of each denominator of formula 5 and will bring scarce difference on final figures of rates of emigration. Estimates of $e_1$, $e_2$ and $S$ show different figures by two cases in which averaged number of ovulation is 2.8 or 1.6, and give some differences to individual figures of $r_1^1$, $r_2^1$, $r_1^2$ and $r_2^2$, but hardly bring difference to rates of emigration of their relative values.

Significant difference is seen in figure of $r_2^2$ calculated from formula 6 for area C between two cases including marking data in 1957 or not (see Table 42). According to detailed records in marking logs, in spite of scantiness of number of whales marked, those marked in closely neighbouring areas at approximately same time are recaptured in closely neighbouring areas again in a successive year. This makes figure of $u$ for this year higher, so that some bias is brought to figure of $r_2^2$. Therefore it is more appropriate that the data in this year is excluded. Thus after being corrected with $f$ and $g$ coefficients and adopting figures of $e_1$, $e_2$ and $S$ in the case which average number of ovulation is 1.6, rates of emigration was finally calculated from data of marking investigation excluding these in 1957. On the other hand, regarding area A it is assumed from yearly fluctuations of frequency of occurrence of blood type that relative size of populations I and II which migrate to this area vary from year to year. But analysis stated above for area C could not be performed for area A because of scantiness of number of whales marked and recaptured in each year, so that intact figures of $r_1^1$ and $r_2^1$ obtained from formulas 5 and 6 are used for calculation of rates of emigration.

Next problems to be discussed are how do ecological factors during migration of whales effect upon the results in previous discussions. Regarding ecology of whales in general, some degrees of seasonal or

geographical segregations by sex, pregnancy and some other physiological factors have been observed. In the north Pacific finback whales, however, slight segregations by pregnancy only have been observed. Sufficient data to estimate quantitatively biases in rates of recapture which seem to be caused by individual factors have not been obtained yet. But the fact, that rates of recapture $r_2^2$ for area C against number of survivor in catch keep approximately constant value from year to year, would suggest that the above-stated various factors against biological segregations hardly effect upon rates of recapture finally. On the other hand, such analysis has not been performed for data on area A, so that it must be kept in mind that some degree of biases in rates of recapture are involved. This means that ratio of $\frac{r_1^2}{r_1^2+r_2^2} : \frac{r_2^2}{r_1^2+r_2^2}$ includes some degree of error. Errors in this ratio and in rates of emigration which is caused by bias between periods for blood typing and those for marking investigations, might bring somewhat effects upon gene frequency of population I and figures of $N_1$ and $N_2$. But these figures must have sufficient precision to discuss problems involved in present paper. Higher precision could be expected through discussions with additional data hereafter.

*Other biological evidences suggesting existence of local populations.* After comparing morphological characteristics, following differences, which may confirm the existence of local populations, have been observed between whales from East China Sea and those from areas around Aleutian Islands That is, whales from East China Sea 1) have lower growth rate in body length, attain sexual maturity at averaged body length of 57 or 58 feet in male and of 60 or 61 feet in female approximately three feet smaller (Fujino, unpublished data), 2) are different significantly in external body proportions (Ichihara, 1958) and in shape of skull (Fujino and Ichihara, unpublished data), and 3) have shorter baleen plates in same ages and in same body lengths than those from areas around Aleutians. Full discussions on these points will be published later (Fujino, to be published in next issue). Such significant difference have not been recognized between whales from area off Kamchatka and those from area of east Aleutions. Therefore it can be assumed that differentiation between populations I and II is situated in earlier stage than that between those and populations in East China Sea. In the areas of Okhotsk sea and off Pacific coast of Japan sufficient investigations have not been carried out in recent years because of poor catch, but shape of baleen plates from these whales reveal same characteristics as those from Aleutian waters (Fujino, unpublished data).

Results of discussions in the present paper can be summarized as

follows.

1) After studying technical problems in large scale of blood typing investigations on whales, standardization in basic methods has been established as follows. Glycerol freezing technique has potential value in preserving intact erythrocytes used for analysing blood type antigens, and standard reagents can be preserved by adding preservatives at concentration of 0.5% carbolic acid or 0.1% sodium azide and by being kept frozen for several years in good condition available for testing. Preservatives will serve against accidental warming during transportation between central and field laboratories.

2) Blood type antigens and other serological constitutions were analysed in four species of baleen whales and three species of toothed whales and allele systems in some species among these were discussed. Especially in Ju blood types of finback whales, two allele system was denied and two kinds of three allele systems were discussed.

3) Racial study on the north Pacific finback whales were performed by means of population genetics with blood types. As Ju antigens have higher precision than Bp antigens in large scale of investigation, the former was used for quantitative analysis.

4) Basing upon non-random geographical distribution in frequency of occurrence of blood types and rates of emigration of marked whales, it became to be obvious that different local populations of finback whales distribute in various areas of the North Pacific including East China Sea, west and east sides' areas around Aleutian Islands.

5) According to comparison of continued ratios of blood type gene frequencies of populations from neighbouring three areas, finback whales in East China Sea belong to a local population which is isolated from those in areas around Aleutians. Furthermore, this fact was confirmed significantly by comparison of morphological characteristics such as growth rate in body length, body length at which sexual maturity is attained, external body proportions and shape of skull, shape and growth rate of baleen plate.

6) Rate of emigration which was calculated from results of marking investigations strongly confirm the existence of the two different populations in the west (population I) and east (population II) sides' areas around Aleutian Islands which was previously clarified by blood typing investigations, and that population I hardly migrate to the area north of east Aleutian (area C), but population II distribute not only to area C but also to area off Kamchatka (area A). In other words, migratory ranges of populations I and II are overlap in the areas A and south of east Aleution (B), but relative sizes of both populations which actually migrate to these areas fluctuates from year to year.

7) Gene frequencies of populations I and II are estimated by blood type gene frequencies observed in various areas and rates of emigration of marked whales through three allele B system. These includes $p_1$ : .334, $q_1$ : .074, $r_1$ : .592 in population I and $p_2$ : .896, $q_2$ : .002, $r_2$ : .102 in population II. These figures will be useful for estimating annual ratio of mingling between populations I and II in various areas around Aleutian Islands, although some bias may be involved in figures of population I. Additional data could be serve to bring these values higher precision.

8) After estimating relative sizes of populations I and II which actually migrate to areas A and C, it became to be clarified that population II has larger stock number than the other. Higher precision in estimating these actual figures should be expected by additional data hereafter.

9) Shape of baleen plates of finback whales from area of Okhotsk and Pacific sides of the north eastern Japan is different from that from East China Sea and reveals same type as that from areas around Aleutians, though the data obtained are very scanty so far. Whether whales from these areas belong to population I or other will be discussed after obtaining informations available in future.

10) In spite of fairly abundant annual catch, no recapture of whales, which was marked in the areas around Aleutians has been reported from areas off British Columbia and off California. This fact might suggest existence of another different population in these areas, so that it can be concluded that at least four different local populations of finback whales distribute in the north Pacific Ocean.

## ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Dr. Hideo Omura, Director of the Whales Research Institute, and Prof. Yasuo Suyehiro, University of Tokyo for guiding this study and reading original manuscript.

Assistance in collecting samples and discussing on investigations of staffs of the Whales Research Institute including Dr. Masaharu Nishiwaki, Messrs. Takahisa Nemoto, Tadayoshi Ichihara, Seiji Ohsumi, and Keiji Nasu are also gratefully acknowledged.

Sincere thanks are due to Mr. Takehiko Kawakami and inspectors of the Japanese Fisheries Agency who offered informations on marking investigation, to the whaling companies who helped the author in giving facilities for experiments at landstations and on board factory ships, and to Mr. Teijiro Tajima, Meat Inspection Office, Tokyo, who offered serums of domestic animals.

Mr. Yukio Nose, University of Tokyo kindly gave to the author valuable

suggestions on calculation of the results of marking investigations.

Finally the author would like to record their appreciations of Prof. John E. Cushing, University of California, Dr. George J. Ridgway and Dr. Lucian M. Sprague, Fish and Wildlife Service, Department of Interior, U.S.A. who gave to the author various suggestions and discussions on mutual problems in serology and genetics.

## REFERENCES

BARANOV, F. I. (1918). On the question of the biological basis of fisheries. *Bureau of Fish., Bull.*, 1 (1): Petrograd.

BOYD, W. C. (1950). *Genetics and the races of man.* Boston, Little, Brown and Co.

BRILES, W. E., W. H. MCGIBBON and M. R. IRWIN (1950). On multiple alleles effecting cellular antigens in chickens. *Genetics*, 35: 633–52.

CHITTLEBOROUGH, R. G. (1959). Intermingling of two populations of Humpback Whales. *Norsk Hvalfangst-Tid.*, 48 (10): 510–21.

CUSHING, J. E. (1956). Observations on serology of tuna. *Sp. Sci. Rept.*, no. 183.

CUSHING, J. E., K. FUJINO and K. TAKAHASHI (1959). Glycerol freezing technique as an aid in blood typing of whales. *Sci. Rep. Whales Res. Inst.*, no. 14: 89–100.

FRIEDENREICH, V. and S. WITH (1933). Über B antigen und B antikörper bei Menschen und Tieren. *Zeitschr. Immunitäts.*, 78: 152–72.

FUJINO, K. (1953). On the Serological Constitution of the Sei, Fin, Blue and Humpback Whles (1). *Sci. Rep. Whales Res. Inst.*, no. 8: 103–24.

——— (1954). On the Serological Constitution of the Sperm and Baired-beaked Whales (1). *Sci. Rep. Whales Res. Inst.*, no. 9: 105–20.

——— (1956). On the Serological Constitution of the Fin Whales II. *Sci. Rep. Whales Res. Inst.*, no. 11: 85–98.

——— (1958). On the Serological Constitution of the Fin Whales III. *Sci. Rep. Whales Res. Inst.*, no. 13: 171–84.

——— . Unpublished data.

FUJINO, K. and J. E. CUSHING (1959). Blood typing of dried whale erythrocytes with $^{131}I$ labelled antibody. *Sci. Rep. Whales Res. Inst.*, no. 14: 101–6.

——— (1960). Blood types in Fur Seals. *Science*, 131 (3409): 1310–1.

FUJINO, K. and T. ICHIHARA Unpublished data.

FURUHATA, T. (1957). *Hemotypology, Immunohematology of Blood Groups and Blood Types.* Tokyo and Osaka, Igaku Shoin Ltd., 285 p. (In Japanese).

HIRASAWA, T. (1935). [Parentages of new-blood group factors M and N]. *Hanzaigaku Zassi*, 9: 678–90. (In Japanese)

HOLT, S. J., J. A. GULLAND, C. TAYLOR and S. KURITA (1959). A Standard Terminology and Notation for Fishery Dynamics. *Bull. Jap. Soc. Sci. Fish.*, 25 (3): 245–8.

ICHIHARA, T. (1957). An application of linear discriminant function to external measurements of fin whale. *Sci. Rep. Whales Res. Inst.*, no. 12: 127–90.

INOUE, Y. (1943). [On the Anti-O Antibody in the Eel Sera]. *Tokyo Igakkai Zassi*, 57: 1–55: (In Japanese).

IZEKI, S. and Y. MURAKAMI (1940). Über die serologische Bedeutung von $A_1$, $A_2$ und $A_3$. *Hanzaigaku Zasshi*, 14 (4): 531–533. (In Japanese).

KASAHARA, H. (1950): [Whaling and it's resource in the waters adjacent to Japan]. *Rep. Lab. Nihon Suisan Co. Ltd.*, no. 4. (In Japanese).

KAWAKAMI, T. and T. ICHIHARA (1958). Japanese Whale Marking in the North Pacific in 1956 and 1957. *Norsk Hvalfangst-Tid.*, 47 (6): 285–91.

KAWAKAMI, T. and K. NASU (1956). [*Whale Marking in the areas off Sanriku and Hokkaido and in the northern part of North Pacific, 1955*]. Tokyo, Hogeisenpaku Sobikaizen Association, 99, p.

KOMAI, T., M. CHINO and Y. HOSHINO (1956). Population genetics on the lady-beetle *Harmonia axyridis*. Population Genetics, 45-60, pp. Tokyo, Baifu-kan.

KOSHINO, T. (1938). Bemerkung über Serokonstitution des Kaninchens. *Juzenkai Zassi*, 43: 3385-3403. (In Japanese).

——— (1939). Die Auswertung der Serokonstitution vom Kaninchen beim Gerwinnen des gruppenspezifischen Immunkörpers mittels Menschenspeichels; in besondere in Bezug auf dem Ausscheidungs und seinem Serum typus II. *Juzenkai Zassi*, 44: 2178-2209. (In Japanese).

LAWS, R. M. (1960). *Some Effects of Whaling on the Southern Stocks of Baleen Whales*. Read at a Symposium on 'The Exploitation of Natural Animal Populations' at Durham in March, 1960.

LAWS, R. M. and P. E. PURVES (1956). The ear plug of the Mysticete as an indication of age, with special reference to the North Atlantic Fin Whale. *Norsk Hvalfangst-Tid.*, 45 (8): 413-25.

MIZU, M. (1931). Die Blutgruppenuntersuchungen der Mütter, der Neugeborenen und der Feten. *Hanzaigaku Zasshi*,, 4 (3): 222-266. (In Japanese).

NISHIWAKI, M. (1957). Age characteristics of ear plug of whales. *Sci. Rep. Whales Res. Inst.*, no 12: 23-32.

NOZAWA, T. and OTHERS (1956). [Report on biological investigation of whales taken from northern part of the north Pacific in 1955]. Tokyo, Japan Whaling Association, (In Japanese).

OHSUMI, S., M. NISHIWAKI and T. HIBIYA (1958). Growth of fin whale in the northern Pacific. *Sci. Rep. Whales Res. Inst.*, no. 13: 97-134.

OMURA, H. (1950). Whales in the Adjacent Waters of Japan. *Sci. Rep. Whales Res. Inst.*, no. 4: 27-114.

(1955). Whales in the Northern Part of the North Pacific. *Norsk Hvalfangst-Tid.*, 44 (6): 323-45.

(1959). Bryde's whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, no. 14: 1-34.

OMURA, H. and T. KAWAKAMI (1956). Japanese Whale Marking in the North Pacific. *Norsk Hvalfangst-Tid*, 45 (10): 555-63.

OMURA, H., S. NISHIMOTO and K. FUJINO (1952). *Sei Whale (Balaenoptera borealis) in the Adjacent Waters of Japan*. Tokyo, Japan Whaling Association.

OMURA, H., M. NISHIWAKI, K. FUJINO and S. KIMURA (1957). On the Stock of Baleen Whales in the North Pacific. *Tokyo, Suisangaku-Syusei, University of Tokyo Press* 507-535 pp. (In Japanese).

OTTESTAD, P, (1956). On the Size of the Stock of Antarctic Fin Whales ralative to the Size of the Catch. *Norsk Hvalfangst-Tid.*, 45 (6): 298-308.

OWEN, R. D. (1954). Heterogeneity of Antibodies to the Human Blood Groups in Normal and Immune Sera. *J. Immunology*, 73 (1): 29-39.

OWEN, R. D., C. STORMONT and M. R. IRWIN (1947). An Immunogenetic analysis of racial differences in dairy cattle. *Genetics*, 32: 64-74.

PURVES, P. E. and M. D. MOUNTFORD (1959). Ear plug laminations in relation to the age composition of a population of fin whales (*B. physalus*). *Bull. Brit. Mus. (Nat Hist.), Zoology*, 5 (6): 123-61.

RACÉ, R. R. and RUTH SANGER (1954). *Blood groups in man*. Springfield, Charles C. Thomas Publisher, p. 257-59.

RIDGWAY, G. J., J. E. CUSHING and G. L. DURALL (1958). Serological Differentiation of

Populations of Sockeye Salmon, *Oncorhynchus nerka*. *Sp. Sci. Rep., Fish.*, no. 257.

SCHIFF, F. and H. SASAKI (1932). Der Ausscheidungstypus, ein auf serologischun Wege nachweisbares Merkmal. *Klin. Woch.*, 34: 1426-29.

SINDERMANN, C. J. and D. F., MAIRS (1959). A major blood group system in Atlantic Sea Herring. *Copeia*, 1959 (3): 228-32.

SPRAGUE, L. M. (1959). *Annual Report for the Year Ending June 30, 1959*. U.S. Bureau of Commercial Fisheries, La Jolla Biological Laboratory.

SUZUKI, A., T. MORIO and K. MIMOTO (1959). Serological Studies of the Races of Tuna II. *Rept. Nankai Reg. Fish. Res. Lab.*, no. 11: 17-23.

TAKAHASHI, K. and Y. SUYEHIRO (1957). Serological study on the race of the north Pacific Salmon. Tokyo, Tokyo University. (In Japanese)

TERASHIMA, M. (1942). Analyse der A-Typensubstanzen in Blutkörperchen und in den Organen des Menshen. *Tokyo Igakkai Zassi*, 56: 257-309. (In Japanese).

YAMAGUCHI, K. and K. FUJINO (1952). On the Serological Constitution of Striped Dolphin (1). *Sci. Rep. Whales Res. Inst.*, no. 7: 69-77. & *Proc. Jap. Acad.*, 29 (2): 61-7, (1953).

## APPENDIX. FREQUENCY DISTRIBUTION OF NUMBER OF CORPORA ALBICANS IN PREGNANT FEMALES TAKEN FROM THE NORTH PACIFIC FINBACK WHALES

| | Off Kamchatka (A) | | | | | | | | South of east Aleut. (B) | | | | | | North of east Aleut. (C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 |
| 0 | 1 | 13 | 9 | 4 | 9 | 7 | 2 | 16 | 6 | | | 12 | 8 | 2 | 31 | 25 | 10 | 10 | 8 | 26 |
| 1 | 6 | 12 | 8 | 2 | 7 | 4 | 4 | 12 | 8 | 3 | 2 | 7 | 15 | 1 | 23 | 40 | 19 | 9 | 6 | 14 |
| 2 | 5 | 16 | 9 | 4 | 5 | 6 | 5 | 10 | 4 | | | 16 | 6 | 1 | 16 | 21 | 20 | 14 | 6 | 15 |
| 3 | 2 | 12 | 14 | 2 | 5 | 10 | 5 | 12 | 2 | 1 | | 16 | 4 | | 18 | 33 | 14 | 7 | 5 | 10 |
| 4 | 1 | 11 | 9 | 2 | 11 | 4 | 6 | 10 | 1 | 1 | 2 | 7 | 4 | 2 | 9 | 21 | 9 | 2 | 4 | 14 |
| 5 | 2 | 10 | 8 | 6 | 8 | 4 | 4 | 18 | 5 | | | 12 | 7 | 1 | 12 | 24 | 10 | 4 | 3 | 7 |
| 6 | 1 | 7 | 13 | 2 | 6 | 3 | | 9 | 3 | | | 9 | 10 | 2 | 7 | 16 | 8 | 1 | | 13 |
| 7 | 2 | 10 | 5 | 5 | 12 | 2 | 3 | 12 | 2 | 2 | | 12 | 6 | | 6 | 14 | 4 | 2 | 3 | 10 |
| 8 | 2 | 11 | 5 | | 2 | 8 | 3 | 7 | 4 | 1 | | 8 | 3 | | 3 | 6 | 5 | | 2 | 7 |
| 9 | 1 | 5 | 8 | 2 | 6 | 7 | 3 | 17 | 1 | | | 7 | 5 | | 4 | 5 | 1 | 2 | 2 | 6 |
| 10 | 4 | 3 | 4 | 4 | 5 | 3 | 7 | 6 | 2 | | 1 | 7 | 2 | 1 | 2 | 4 | 3 | 2 | | 1 |
| 11 | 1 | 5 | 2 | | 6 | 5 | 3 | 5 | 3 | | 3 | 5 | 2 | 1 | 1 | 5 | 4 | 2 | 2 | 5 |
| 12 | 1 | | 2 | | 3 | 4 | 1 | 9 | | | | 7 | 4 | 1 | | 2 | 1 | 2 | | |
| 13 | 1 | | 1 | | 3 | 1 | 1 | 7 | | | | 2 | 2 | 1 | | 2 | 1 | 2 | | 1 |
| 14 | | 3 | 1 | | 2 | 1 | 1 | 4 | 1 | | | 1 | 1 | | 1 | | | | | 2 |
| 15 | | | 2 | | 4 | 1 | 1 | 5 | | | | 2 | 1 | | | | 2 | 1 | | |
| 16 | | 1 | | | 2 | 2 | 1 | 1 | 1 | | | 1 | | | | 1 | | | | 1 |
| 17 | | 1 | 1 | | 1 | | | 3 | 1 | | | 2 | | | | | 1 | | | 2 |
| 18 | | | | | 1 | 2 | | 2 | | | | | | | | | 2 | | 1 | |
| 19 | | | | | | | | | | | | 1 | | | 2 | | | | | 1 |
| 20 | | | | | 1 | | | 1 | | | | 1 | | | | | | | | |
| 21 | | | | | 1 | | | | 1 | | 1 | | | | | | 1 | | | 1 |
| 22 | | | | | | | 1 | | | | | | | | 1 | | | | 1 | |
| 23 | | 1 | | | | | | | | | | 1 | | | | | | | 1 | 1 |
| 24 | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | 1 | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | 1 |
| 27 | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | 1 | | | | | | | | | | | | | |
| 29 | | | | | | | | 1 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | 1 | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | 1 | | | | | | | | | 1 |
| 34 | | | | | | 1 | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | | | | | | | |
| 36 | | | | | 1 | | | | | | | | | | | | | | | |
| 37 | | | | | | | 1 | | | | | | | | | | 1 | | | |
| 38 | | | | | | | | | | | | | | | | | | | | 1 |
| 39 | | | | | | | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | | | | | | 1 | | | |
| 41 | | | | | | | | | | | | | | | | | | | | |
| 42 | | 1 | | | | | | | | | | | | | | | | | | |
| Sum | 30 | 122 | 101 | 33 | 102 | 76 | 53 | 167 | 45 | 8 | 10 | 136 | 80 | 13 | 136 | 219 | 117 | 60 | 44 | 140 |

# OCEANOGRAPHIC INVESTIGATION IN THE CHUKCHI SEA DURING THE SUMMER OF 1958

KEIJI NASU

## INTRODUCTION

This paper is the result of investigation conducted by the author in the waters of the Chukchi Sea (Arctic Ocean) during August of 1958. This observation was carried out on board of the "Fumi-maru No. 16", belonging to the Taiyō Fisheries Co., Ltd.

The observation in the Chukchi Sea has begun in Aug. 16, and completed in Aug. 20. During the season, 19 stations were occupied, covering the region shown by Fig. 1.

At each oceanographic station, the records of vertical temperature distribution were obtained from bathythermograph. Planktons were collected almost at all stations and sediments of the bottom were taken

Fig. 1. Location of bathythermograph stations (56–74) and hydrographic stations established by the U.S.C.G.C. Chelan in 1934 (36–39).

at St. 59, 63 and 69 only. Furthermore, a sample for measurement of radio-activity was taken at St. 70.

Materials gathered at the surface include observation of temperature and of chlorinity, dissolved oxygen and hydrogen-ion concentrations of the waters.

The author wishes to express his thanks to Captain Sumio Tanaka and Mr. Eiichi Tanaka, the members of the Taiyō Fisheries Co., Ltd. and the crew on board of the "Fumi-maru No. 16", who helped him during the season.

The author is greatly indebted to Dr. Michitaka Uda, Professor of the Tokyo University of Fisheries, who gave me many kind advices and read through the paper, and to Dr. Hiroshi Niino, Professor of the Tokyo University of Fisheries, who examined samples from the sea bottom.

Thanks are also due to Mr. Katsuo Ohkubo, a member of the Tokai Regional Fisheries Research Laboratory, who measured radio-activity of the waters.

## TEMPERATURE AND SALINITY

Fig. 2 shows the distribution of temperature and salinity at the sea surface. Temperature and salinity at the surface in the Chukchi Sea obtained by the survey, ranged from 3.7°C minimum to 11.2°C maximum. The maximum temperature area located at the WSW off Point Hope, and the isotherms in that area run quite similar to the contour line in the topographical distribution.

Isohaline at the surface, 31.50‰ line, runs parallel to the Alaskan continent. In general, in the eastern area of the Chukchi Sea, the surface sea condition tends to higher temperature and lower salinity, and those isoplethes run in paralleled with the Alaskan coast line as already stated by La Fond & Pritchard (1952). It is especially conspicuous off Point Hope.

In addition, the warm and low salinity water may be considered as due to the influence of heating by solar radiation on ice-melted water. The distribution of water temperature at the surface in the Chukchi Sea is characterized by a decrease from the east to the west. On the other hand, the distribution of salinities show increase from the east to the west and its maximum, 32.00‰ located at near 170°–172°W on 68°20′ N line. The values of salinity decrease from the higher saline area to the Siberian coast, where the water masses are modified into these less than 5.0°C in temperature and 30.00‰ in salinity.

The high salinity in the central part of the Chukchi Sea may be due to the influence by the northward current from the Bering Strait, in the adjacent waters to the Siberian coast. While the low saline water

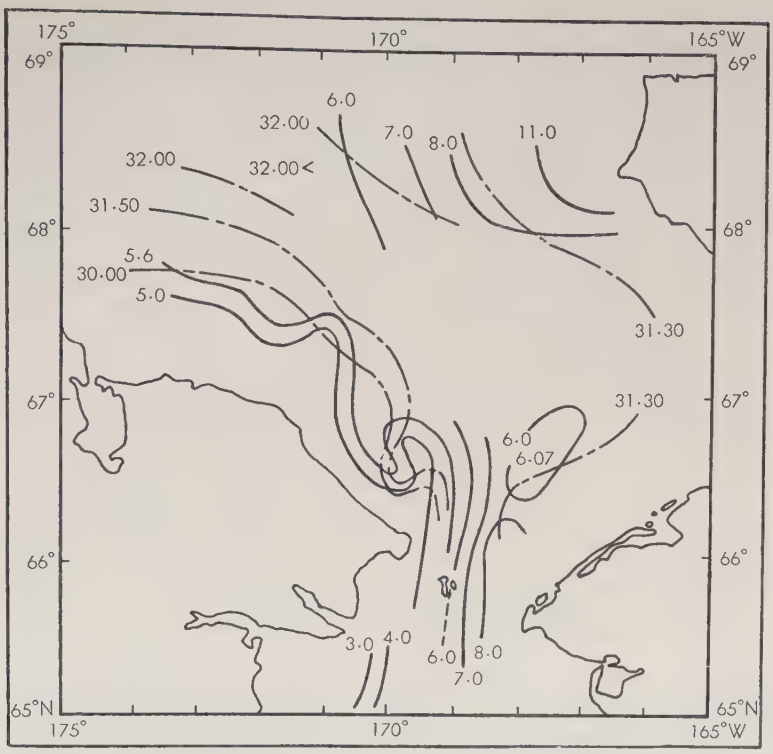



Fig. 2. Horizontal distribution of temperature and salinity at surface. Solid line—temperature. Broken line—salinity.

may be due to the melting ice and the inflow of coastal waters.

From the distribution of temperature and salinity the cyclonic eddy seems to be located in the vicinity of 66°40′N, 170°W. In addition, the coldest portion is found in the north of the Anadyr Bay and its temperature at the surface is below 2.5°C. It seems that the coldest area exists stationary.

In the eddy area near to 66°40′N, 170°W, origin of southward current is considered as the Bering water mass, and northward direction of flow for east of the Diomede Islands. That is, from distribution of surface temperature as denoted by G. Ratmanoff (1939) northward current is affected by the cyclonic eddy of large scale located near to 67°30′, 170°W and its flow extends to southward.

The cold water mass along the Siberian coast flows with speed of about 1 knot (G. Ratmanoff, 1939) and it formed oceanic front with the northward Bering water mass. Moreover, observation from the vessel many foams were recognized on the front. It is clear that the collision of those water masses was remarkable at its situation of the front. Comparatively value below 6.0°C was found at near 66°40′N,

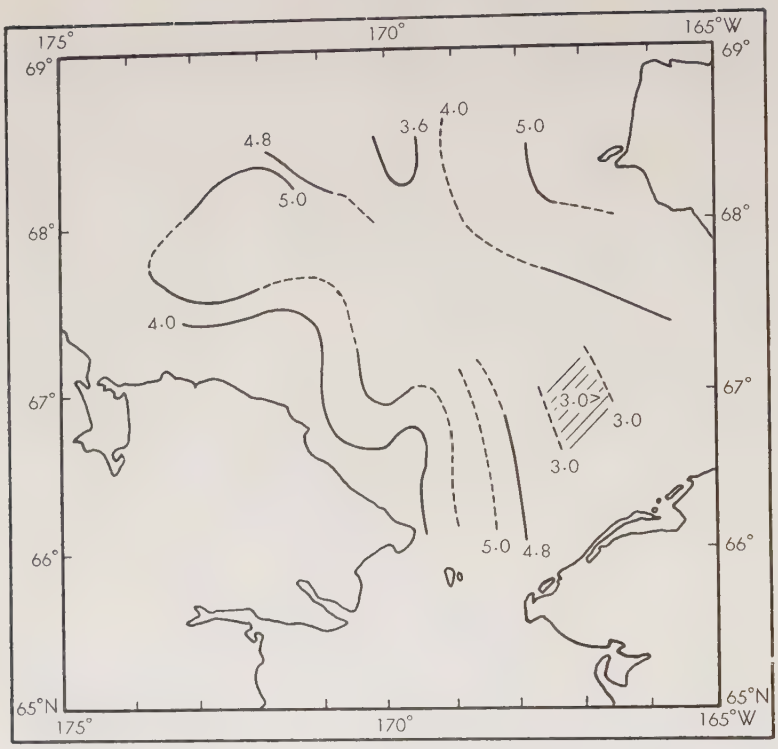



Fig. 3. Horizontal distribution of temperature at 25 m.

167°30′W due to upwelling around by the bank located in the north of Prince of Wales.

A northward flow was shown by all kind of surface observations carried out from the Bering Sea to the Chukchi Sea. Moreover, northward flow in the Bering Strait was already stated by Barnes and Thompson (1938) and Uda (1959, 1960), the water belonging this current is divided into two types of water in the center of Strait (Goodman et al., 1942).

## VERTICAL DISTRIBUTION OF TEMPERATURE

It is well-known that the thermocline develops in the summer season under the influence of heating by the solar radiation in high latitude. The thermocline existed at the Chukchi Sea and also conspicuous one at St. 59–63. The steep vertical gradient of temperature was found at St. 62 and 63, forming most notable thermocline. It is a characteristic feature that the shallow depth of the thermocline at St. 62, ranged from 5 to 10 m depth. Off Point Hope, at St. 63 the maximum 11.7°C was observed at 7 m depth. Such sub-surface maximums in temperature were frequently observed at the north of 70°N near the boundary of

the ice zone (La Fond & Pritchard, 1952).

Bathythermograph data taken from the Chukchi Sea shows that during the summer the thickness of the upper mixing layer was mostly less than about 15 meters depth. Accordingly, it seems to be less than 15 meters approximately in which the influence of heating by solar radiation attains during the summer season. In addition, the upper mixing layer in northern part of North Pacific, is generally less than 20 meters depth (Fleming, 1955).

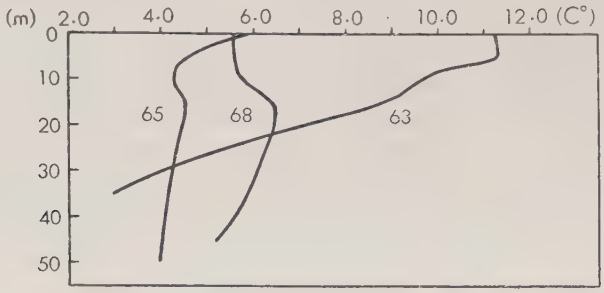



Fig. 4. Station curves of temperature.

In the observation carried out at St. 63, surface temperature rise to 11.0°C or more in midsummer. According to the data obtained by USSR research vessel, the vertical distribution of salinity at near St. 63, indicates most homogeneous pattern from the surface to the bottom layer.

As shown in Fig. 4 the gradient of temperatures to vertical direction, are larger in the eastern part than the west, and the differences between the max. and min. temperature, at St. 66, 67, 69 and 71 were less than 1.0°C. Especially, the water column at St. 69 was well mixed from the surface to the bottom and the vertical temperature below 5 m depth was perfectly homogeneous with 5.5°C. It seems to represent sinking by the convergence which was formed in between the Siberian coastal water and northward flow water from the Bering Sea.

The vertical distribution of temperature along the line at 68°20′N is shown in Fig. 5. It indicates that the horizontal distribution of temperature at the surface layer, decreases toward the west and increases toward the east, meanwhile in the bottom layer below 40 m depth, temperatures increase from the east to the west. The cold water with temperature less than 3.5°C at St. 63 locates from 35 m depth to bottom. Warm water layer at St. 66 was found above 30 m depth. It should be due to the Bering water mass which flowed into the north from the Bering Strait. Comparatively the cold water mass locates at St. 65 above 5 m depth with considerable thick layer. It may be affected by the southward flow

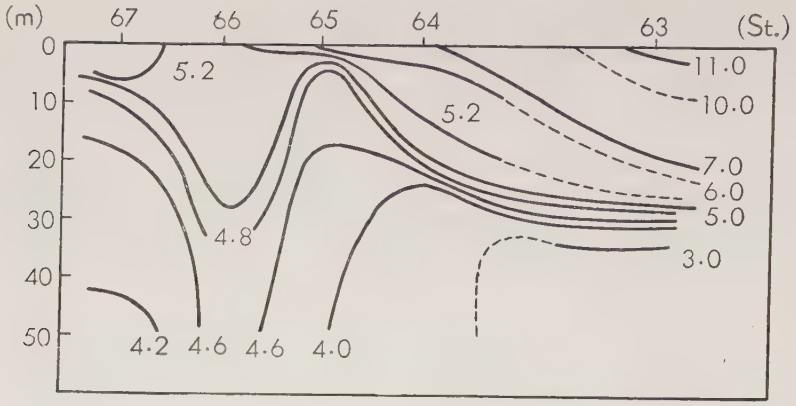



Fig. 5. Profile of temperature along the latitude of 68°20′N.

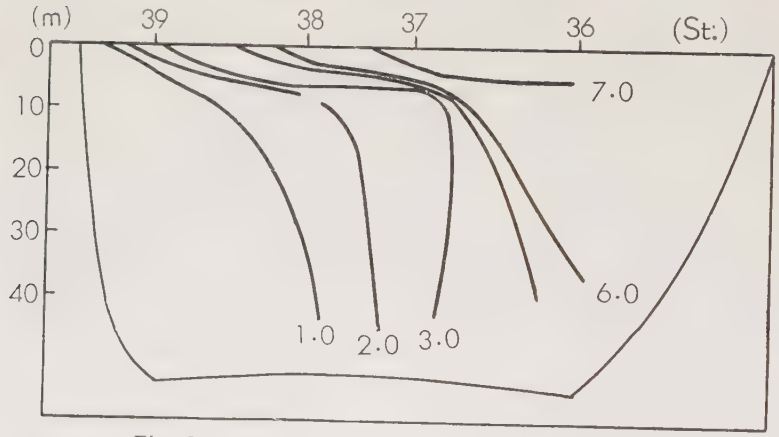



Fig. 6. Profile of temperature along the A-line.

from the waters near the North Poles. Hereby, an oceanic frontal surface is formed and the water mass is divided into two types at the eastern part and the west.

As a rule, the thermocline in the Chukchi Sea is more developed on the side of Alaskan waters than that on the side of Siberian waters and its depth, as stated by La Fond Pritchard (1952), increases from the east to the west. Basing on the vertical distribution of temperature the vertical convection in waters is supposed to be more developed to the west.

Next, the profile of temperature along the A-line, is shown in Fig. 6*. It shows that the Alaskan warm water mass in the Bering Strait locates from the Diomede Islands to the east area. Moreover, the cold water mass located at the west of the Alaskan warm water mass, has shown

* Fig. 6 was drawn by use of data obtained by United States Coast Guard Cooperated with the Oceanographic Laboratories of the University of Washington in 1939.

a flow with general northward direction, and turning to the north-west. This cold water mass indicates subsidence at St. 37. It seems that a convergence might be formed between the warm water mass at the east and the cold water mass at the west.

## DENSITY

The density of sea water depends upon the temperature and salinity. Usually, the general distribution of the density is roughly parallel to the isotherms and isohalines (solenoidal field).

The horizontal distribution of density at the surface is given in Fig. 7, in which the isopycnal of maximum value above 25.00 runs in NNW direction from the central part of Bering Strait meandering to the central part of the Chukchi Sea. It corresponds to the northward flow from the Bering Sea.

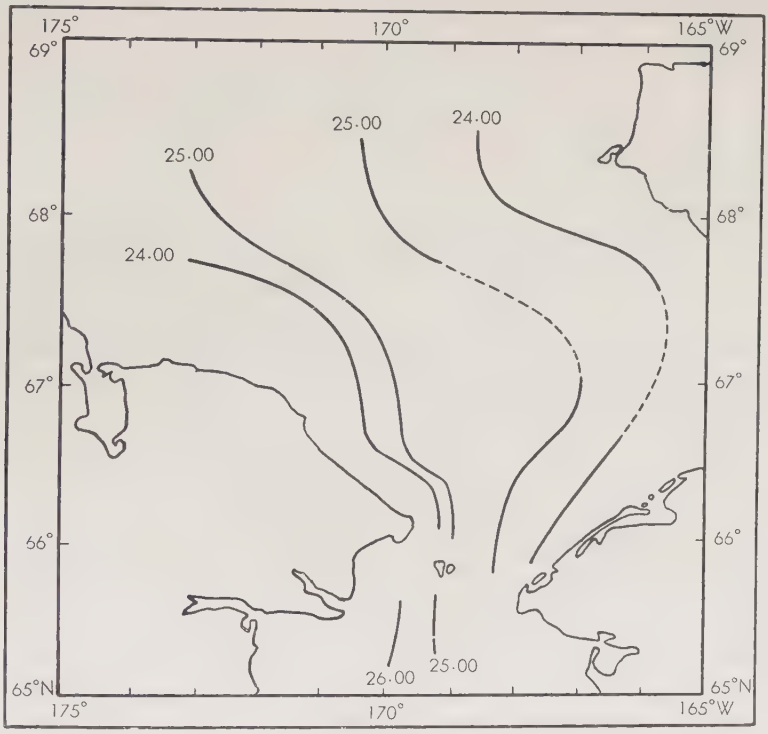



Fig. 7. Horizontal distribution of $\sigma_t$ at surface.

Lower density waters were found along the Alaskan and the Siberian coast. Furthermore, along the Alaskan coast the minimum density is found in Kotzebue Sound (La Fond & Pritchard, 1952). Those lower density along the coasts seems to be due to the melted ice-water in addition to the run-off from the land.

The isopycnic line of 24.00 in the Alaskan waters is roughly parallel to the coast and 25.00 line is parallel to the west of 24.00 line. In the Siberian waters the lines of 25.00 and 24.00 are roughly parallel to the coast. Furthermore, the density varies most rapidly in this region. This condition is brought about by the convergence formed between the Siberian coastal waters and the central waters of the Chukchi Sea.

## DISSOLVED OXYGEN

The horizontal distribution of dissolved oxygen at the surface is given in Fig. 8. The concentration of dissolved oxygen at the surface in the coverage area of observation varied from 9.03 cc/L maximum to 7.17 cc/L. An area with the minimum concentration was found off Point Hope, which corresponded to the area in the maximum temperature. The highest concentration was found at near 68°10′N, 173°00′W off Siberian coast.

Isopleth of 7.50 cc/L extends meandering from the center of Bering Strait to the north-east. Proceeding eastward from the isopleth of 7.50 cc/L the water of relatively low concentration of dissolved oxygen below 7.50 cc/L extends broadly.

In the western part, 7.5, 8.0 and 8.5 cc/L isoplethes are parallel to each other, and those isoplethes were concentrated more densely than the eastern area. This phenomenon is considered due to the convergence between the Siberian water mass and the Alaskan water mass as already denoted in the chapter of temperature. Concerning the horizontal distribution at the surface, the oxygen concentration is low along the Alaskan waters and high along the Siberian waters.

## HYDROGEN-ION CONCENTRATION (pH)

The hydrogen-ion concentration was determined by a comparator for sea water which consists of 2 series of color standard solutions, one was Cresol Red and the other was Tymol Blue. The horizontal distribution of pH at the surface is shown in Fig. 8. The pH values taken by the observation in the Chukchi Sea are about 8.15 to 8.30. The distribution of pH roughly corresponds to that of dissolved oxygen. The waters with relatively lower concentration of pH below 8.20 extends to the Alaskan waters a like to the area below 7.50 cc/L in dissolved oxygen.

Isopleth of 8.20 extendeds from the Bering Sea to the NNW direction, and runs parallel to the west of 8.30 line. The horizontal distribution of pH shows its increase from the east to the west and the closely con-

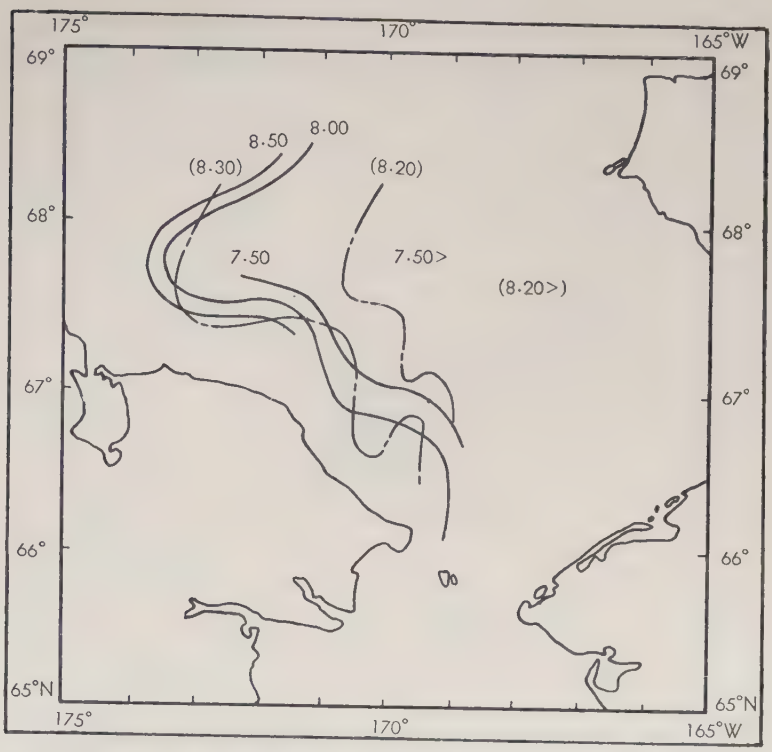



Fig. 8. Horizontal distribution of dissolved oxygen and pH at surface. Solid line—dissolved oxygen. Broken line and parenthesis—pH.

densed isopleth at about 170°W longitude.

It is well-known that the pH values become high when the photosynthetic activity of marine plants have reduced the content of $CO_2$ (Sverdrup et al., 1946). The waters of high concentration of pH were also characterized by higher concentration of dissolved oxygen. Consequently, the productivity in the sea water might be inferred indirectly by the values of pH. In general, the productivity in the Chukchi Sea tends to increase in the west and decrease in the east.

## WATER COLOR AND TRANSPARENCY

The colors of the sea water were determined by the Forel's scale. Fig. 9 indicates the distribution of water colors. In the investigated area the minimum value of color of water observed at near 66°30′N, 168°W and the maximum value (4–5) was found at the north of 67°N, 168°W.

Value of 5 in water color extends widely from the central part of the Chukchi Sea to the Siberian waters.

Transparency by Secchi disc varies from 7 to 12 m and those isoplethes is located like a isotherms in the distribution. That is, the isoplethes of

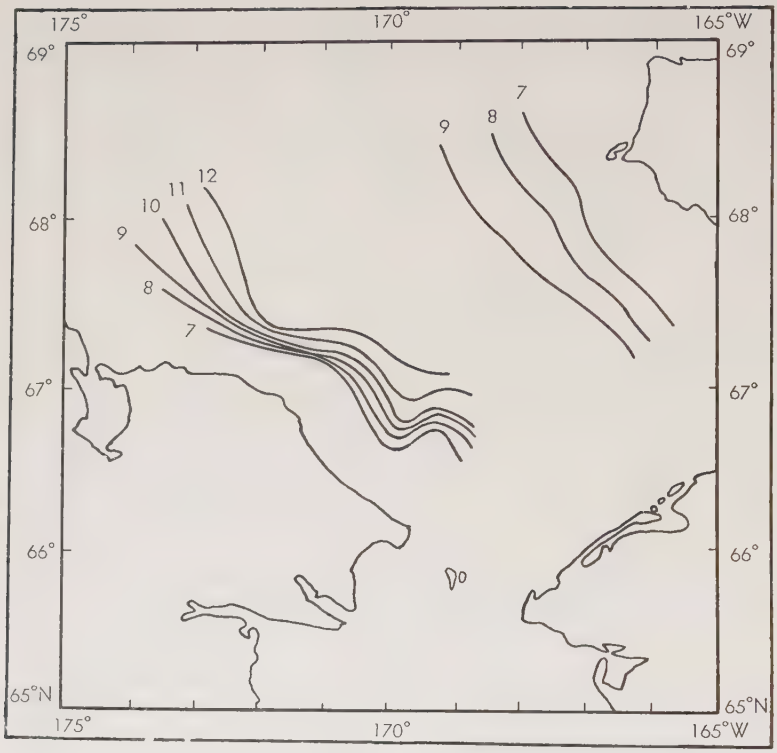



Fig. 9. Iso-line of transparency.

7, 8 and 9 m run parallel to the Alaskan coast and to the Siberian coast, the isoplethes of 7–12 m more or less meander. Lateral intervals of those isoplethes are roughly similar to the dissolved oxygen and hydrogen-ion concentration. It is clear in the distribution of the isopleth of transparency that the discontinuous line was formed by the different water masses along the Siberian coast.

## GENERAL OCEANOGRAPHIC CONDITION

Fig. 10 indicates the regions of higher dissolved oxygen and hydrogen -ion concentrations. Furthermore, the boundary line inferred from temperature and salinity, and the current rips observed from the ship were also shown in Fig. 10. A presumptive current-pattern was indicated from data obtained by this investigation, referring to previous data. It revealed a cyclonic eddy located at near 67°30′N, 170°W. At near 66°40′N, 170°W another relatively conspicuous small cyclonic eddy seems to be formed due to the northern eddy and the southern coastal waters along the Siberian coast.

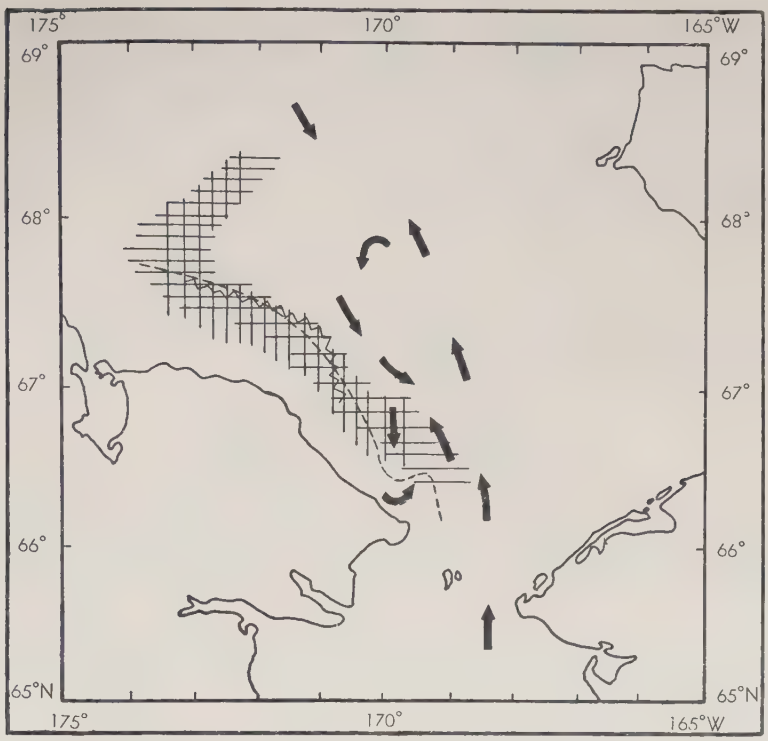



Fig. 10. Summarized oceanographic condition.
Longitudinal line—high value regions of pH. Lateral line—concentrated area of dissolved oxygen. Arrow—presumptived current. Dotted line—boundary line of water mass. Undulating line—current rips were observed from the ship.

General oceanographic conditions are as follows:

Temperature: higher in the east and lower in the west.

Salinity: higher in the central region, and lower to the east and the west.

Dissolved oxygen: higher in the west and lower in the east.

Furthermore, marine productivity seems to be higher in the Siberian waters and low in the Alaskan waters.

## SEDIMENT OF THE BOTTOM

Bottom sediments were sampled with a extemporizedly made dredge from the sea bottom at about 50 m depth. The dredge also brought up the specimens of bottom life.

Samples collected at each station are as follows:

St. 59. fine sand—round sand grains round consist of quartz, felsper and pyroxene without life.

St. 63. gravel—gravels consist of andesite, quartz trachyte and hornstone without life.

St. 69. sandy silt with pebble—Sands consist of quartz and felsper with many spong spicule.

Furthermore, few diatoms were found in those sediments. The gravels were sandstones and quartz trachyte.

## RADIO-ACTIVITY OF SEA WATER

St. 70—Result of measurement for sample 637 cc, radio-activity was not recognized at all ($-2.0 \pm 1.1$ CPM).

## DISTRIBUTION OF WHALES

Inspection in the previous reports (Nikulin, 1947; Data obtained by "Yūki-maru" in the Arctic voyage of 1927) showed that larger whales in the Chukchi Sea were fin, humpback, greenland, right and gray whales.

Fig. 11 shows the locations where all the larger whales were observed from the "Fumi-maru No. 16". Also the Fig. 11 indicated the locations where gray whales were observed.

The number of the sightings during the season are as follows:

| | |
|---|---|
| Fin whale | 1 |
| Right whale | 2 |
| Gray whale | 82 |
| Unknown | 1 |
| Total | 86 |

Only one fin whale was observed around 50 sea miles off west of Point Hope. On Aug. 22, 1927 many fin whales were seen from "Yūki-maru" in the cyclonic eddy area at about 66°40′N, 170°W. Fin whales were seen off Cape of Serdzekamen and in the Bering Strait by the observations from the lands. 70 fin whales were seen in October.

Consequently, many fin whales seems to migrate around the Siberian waters in the Chukchi Sea at least from the early summer to October.

78 gray whales were seen in the convergent area close to the Siberian coast on August 20. These whales seem to have been fed on the livings concentrated by the convergence.

Many gray whales were observed at the east of the St. Lawrence Island in the Bering Sea. It is well-known that the gray whales migrate from the Bering Sea to the Arctic Ocean. Migration route of gray whales from the northern part of the North Pacific to the Bering Sea have been stated (Kellogg, 1929; Gilmore, 1955; Ichihara, 1958). The

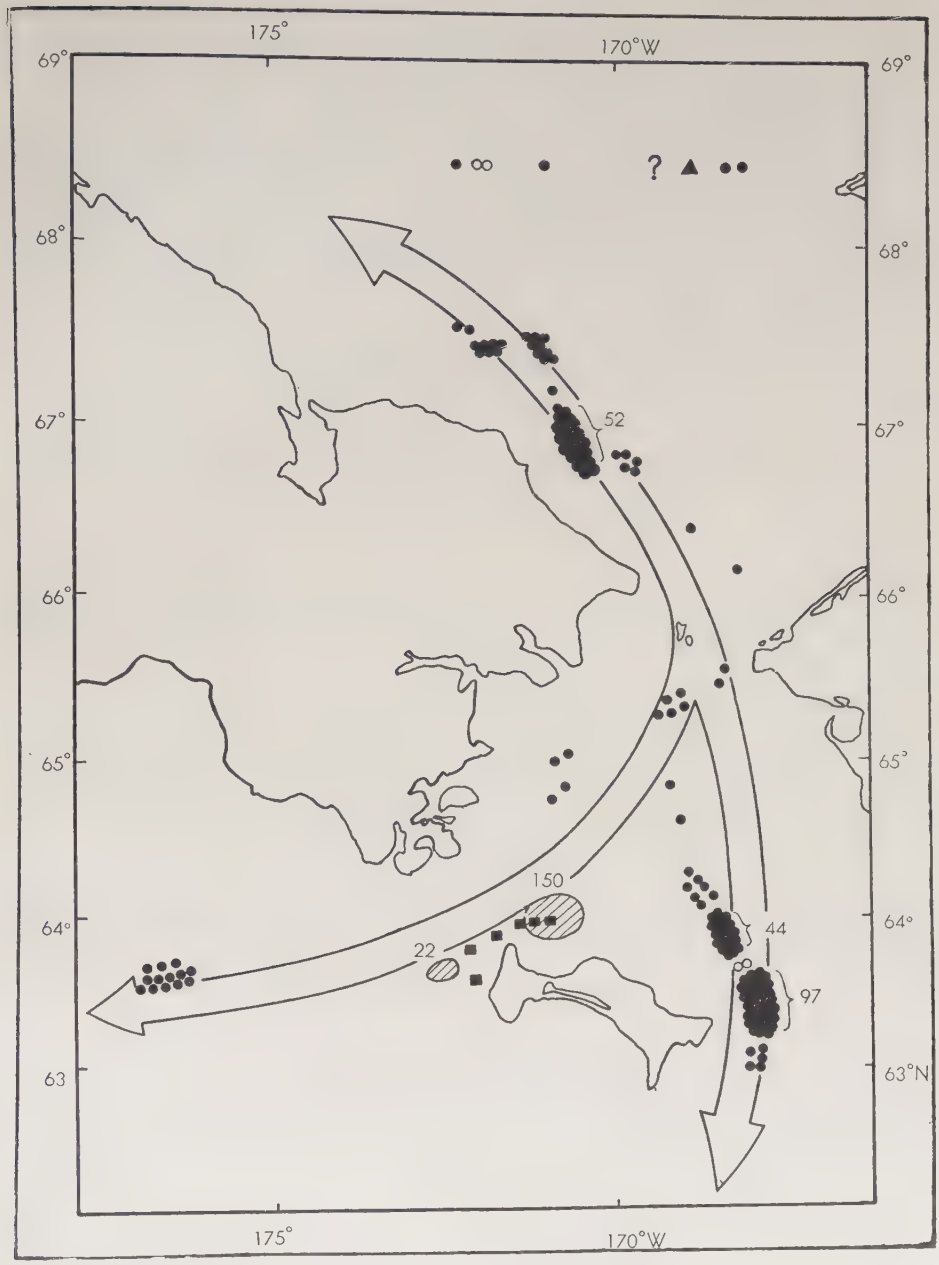



Fig. 11. Location of sighted whales.
Black circle—gray whale. White circle—right whale. Black triangle—fin whale. Question mark—unknown. Black square—sighted location on July 28th, 1957. Oblique line—sighted location on Aug. 2nd, 1955. (Black square and oblique line indicate the gray whales.)

author wishes to keep his opinion that there might be a migration route of the gray whales at the east of the St. Lawrence Island, too.

## SUMMARY

1. The oceanographic and whales sighting survey in the Chukchi Sea was carried out from Aug. 16 to Aug. 20.
2. The water temperature at the sea surface indicates a trend to decrease from the east to the west. On the other hand, salinity shows its increase toward the west and its maximum area located at the central part of the Chukchi Sea. The salinity decreases from the maximum area to the the Siberian coast.
3. The cyclonic eddy seems to locate at near of 66°40′N, 170°W.
4. The vertical gradient of water temperatures are greater to the east and less to the west. The horizontal distribution of temperature at the surface layer decreases toward the west and increases toward the east, meanwhile in bottom layer below the 40 m depth, temperature increases from the east to the west.
5. The maximum values of density were found at the central part of the Chukchi Sea.
6. The horizontal distribution of dissolved oxygen at the sea surface shows the lower along the Alaskan waters and the higher along the Siberian waters.
7. The values of pH increased from the east to the west, and the isolines condensed closely at about 170°W longitude.
8. Marine productivity in the Chukchi Sea appears to increase in the western part and decrease in the eastern part.
9. During the season number of sighted whales are 1 fin whale, 2 right whales, 82 gray whales and 1 unknown whale.
10. The author wishes to keep his opinion that there might be a migration route of the gray whales at the east of the St. Lawrence Island, too.

## REFERENCES

BARNES, C. A. and T. G. THOMPSON (1938). Physical and chemical investigations in Bering Sea and portions of the North Pacific Ocean. *Univ. Wash. Publ. Oceanogr.*, 3(2): 35–79 and Appendix, 1–164.

FLEMING R. H. (1955). Review of the oceanography of the northern Pacific. *Intern. North Pacific Fish. Comm., Bull.*, no. 2: 1–43.

GILMORE, R. M. (1955). The return of the gray whale. *Sci. Amer.*, 192: 62–7.

GOODMAN, J. R. and J. H. LINCOLN et al. (1942). Physical and chemical investigations: Bering sea, Bering Strait, Chukchi Sea during the summers of 1937 and 1938. *Univ. Wash. Publ.*, 3(4): 8–103.

ICHIHARA, T. (1958). Gray whales observed in the Bering Sea. *Sci. Rep. Whales Res. Inst.*, no. 13: 201–5.

KELLOGG, R. (1929). What is known of the migration of some of the whale-bone whale. *Smithsonian Rep.*, 2997.

LaFOND, E. C. and D. W. PRITCHARD (1952). Physical oceanographic investigations in the Eastern Bering and Chukchi Seas during the Summer of 1947. *J. Mar. Res.*, 11(1): 69-86.

NIKULIN, P. G. (1947). O raspredelenii kitoobraznykh v moriakh, omyvaiushikh Chukotskii poluostrov. *Izvestiia TINRO*, 22.

RATMANOFF, G. E. (1939). [Chukchi Sea] *Soviet North Pole*, no. 9.

SVERDRUP, H. U., M. W. JOHNSON and R. H. FLEMING (1946). *The Ocean*. New York, Prentice-Hall, Inc., pp.

UDA, M. (1959). Oceanographic seminars. *Fish. Res. Bd. Canada.*

——— (1960). Oceanography of the Sub-arctic Pacific (in press). *Fish. Res. Bd. Canada. Ms. Rept. 51: 44-58.*

—— — (1960). On the fluctuation and prediction of ocean temperature in the North Pacific.

# ELECTROCARDIOGRAPHICAL STUDIES ON BOTTLE-NOSED DOLPHIN (*TRUSIOPS TRUNCATUS*)

KIKUJI TOKITA* AND ECG RESEARCH GROUP**

So far as the authors know, little studies on ECG of the whale have been reported. This paper deals with ECG of *Trusiops truncatus* which the authors had opportunity to obtain on July 18, 1957, when they were transported alive by trucks overland, from fishing-port Arari to Enoshima Aquarium in which they were to be reared.

The reason to study ECG of the whale is as follows. After the report on digitalis in 1932, Tokita and his collaborators published a paper on the mechanism of its effect on heart-rate in 1951 and 1952, a new aspect of the regulation mechanism of autonomic nerve. This stimulated the authors to begin studies in order to reveal the heart-rate regulation mechanism by collecting the ECG of laboratory animals and those in zoo, extending from mouse to elephant, rice-bird to crane, and killifish to commom boa. In the course of the studies, the authors were afforded this opportunity.

## CONDITION OF WHALE AND ECG-RECORDING

Before the transportation, Trusiops had been reared for two weeks to a month in Arari Bay with squids or fishes. ECG-recording was made at the port, immediately after they were loaded on auto-trucks, next at Mishima after 4 hours and finally at Enoshima after 8 hours. On the truck, one side of the animal body was immersed in sea-water contained in a canvus tank surrounded by ice-pillars, and the other side was covered with blancket moistened with the sea-water. The road passed through high grounds between Arari and Mishima, and through the Hakone Mountain, about 1,300 meters high between Mishima and Enoshima. Water temperature in the canvus tank was 23°C at Arari and 30°C at Mishima and Enoshima. Body-weight of Trusiops was 260 to 300 Kg, but an infant was 110 Kg. Unfortunately, one of the loaded died on the truck at Arari, but the other four reached safely to Enoshima and are still living.

To induce ECG, electrodes (Injection needle) were implanted into the body at the spots corresponding to those of the human body, or the

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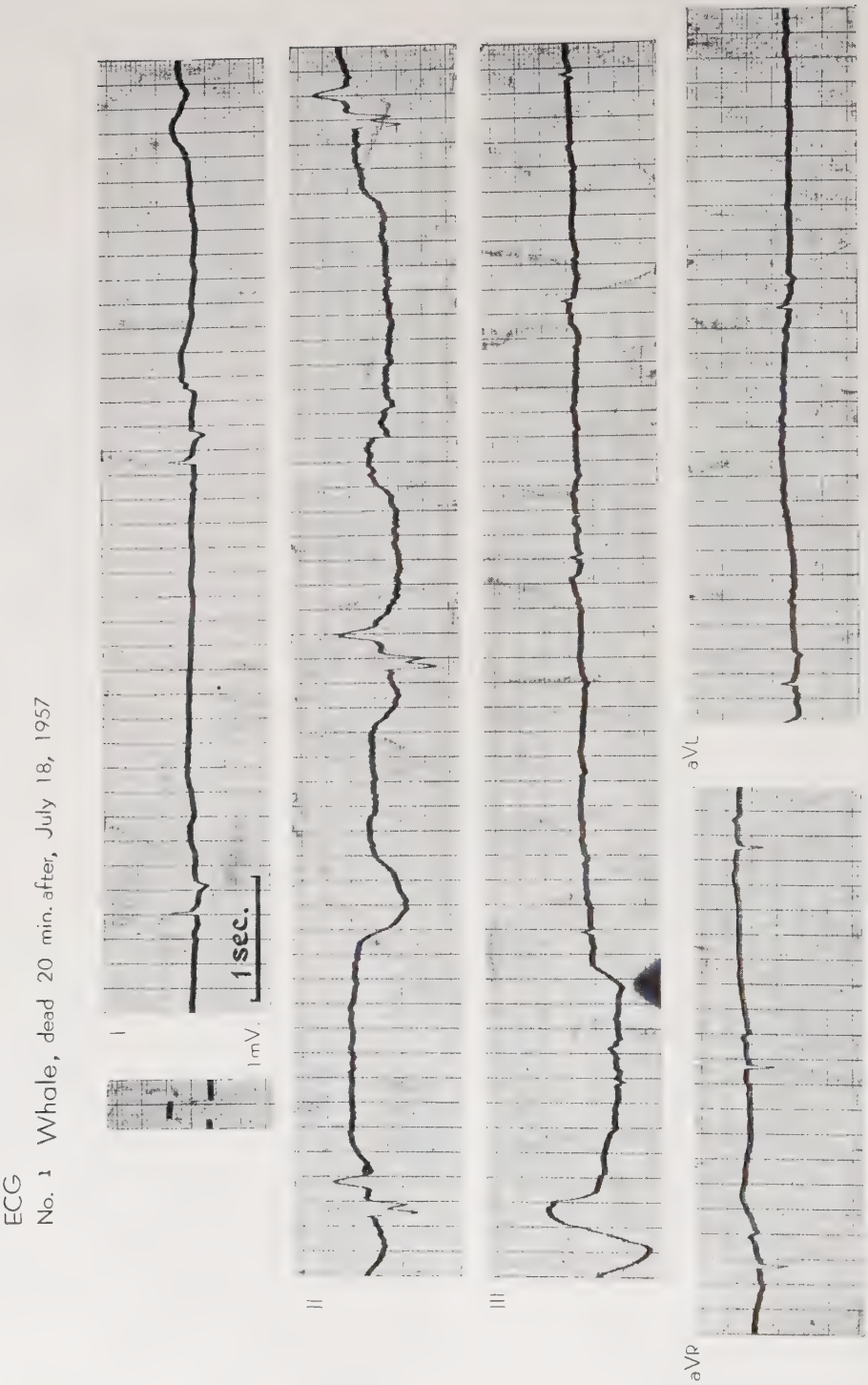
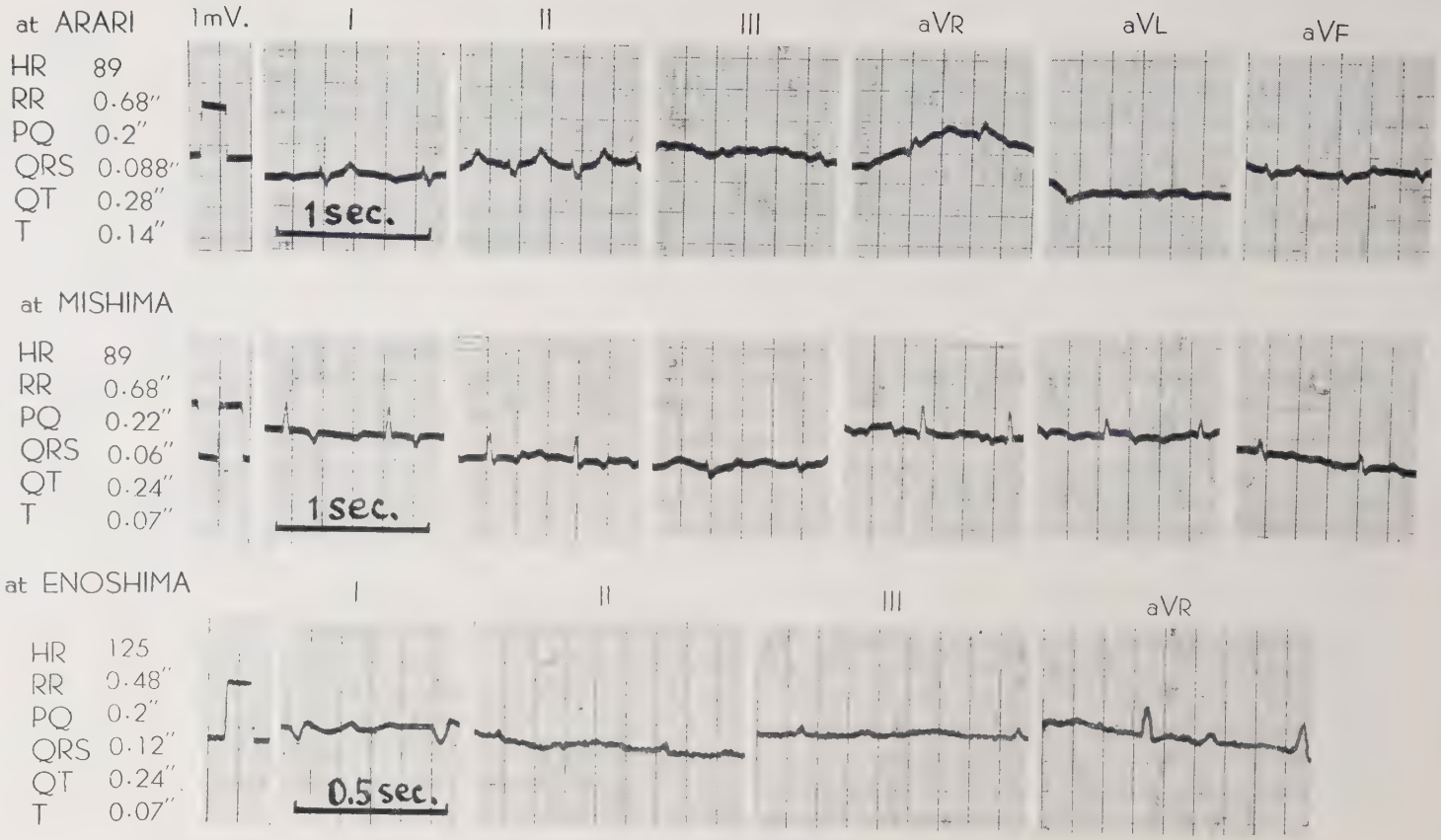
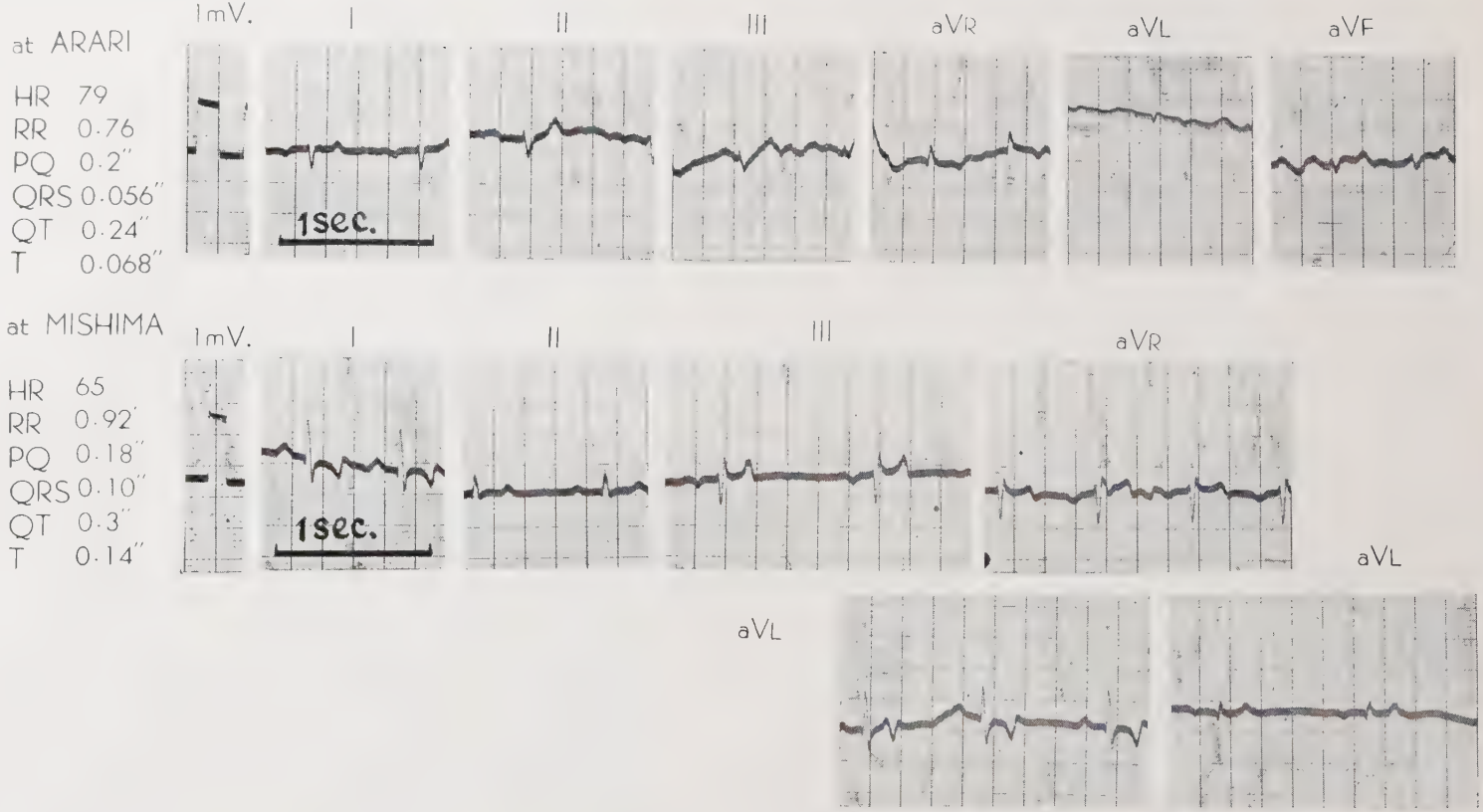

ECG
No. 1 Whale, dead 20 min. after, July 18, 1957
I
1 sec.
1mV.
II
III
aVL
aVR

ECG

No. 2 Whale, July 18, 1957



ECG
No. 3 Whale, July 18, 1957



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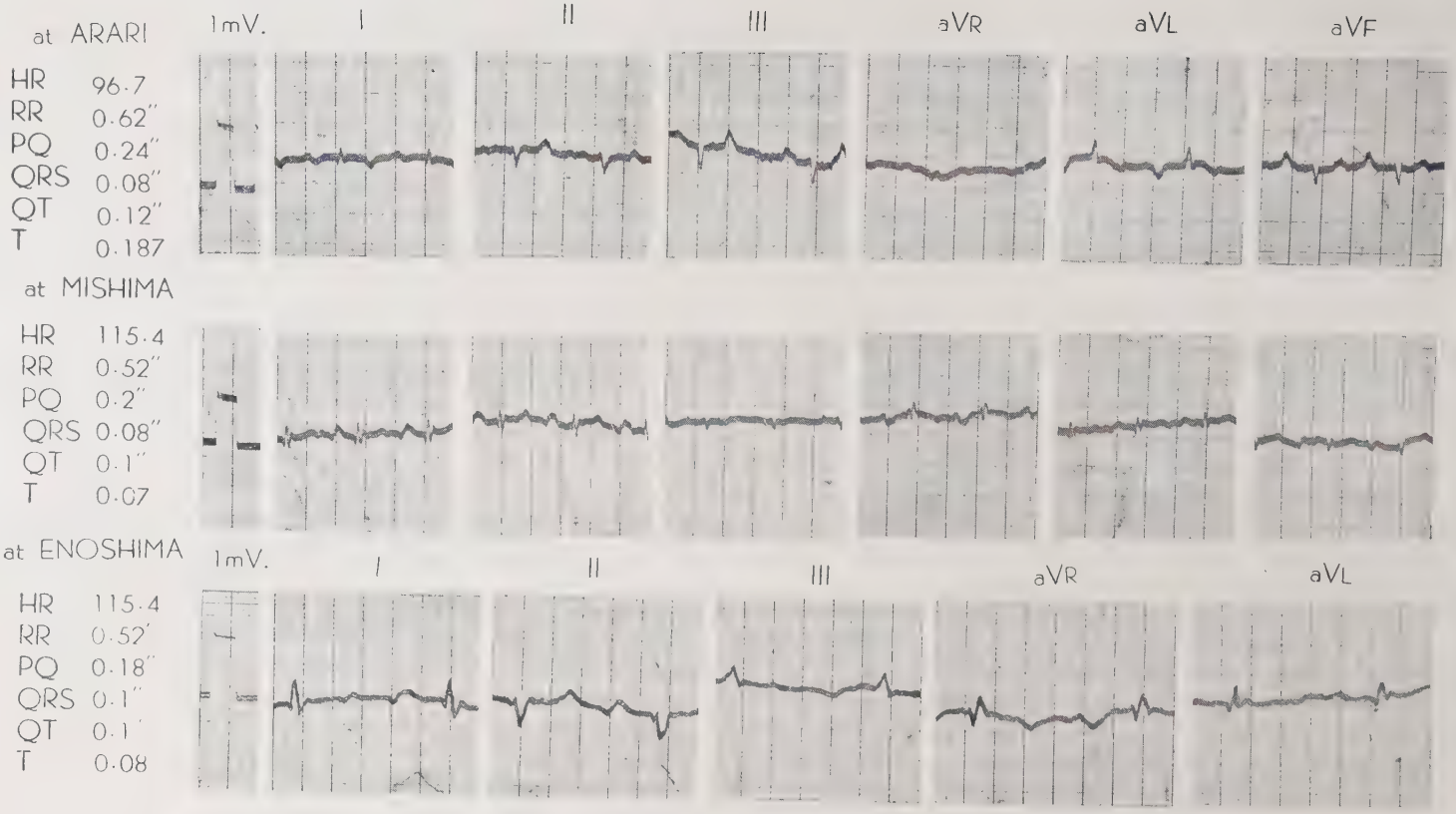
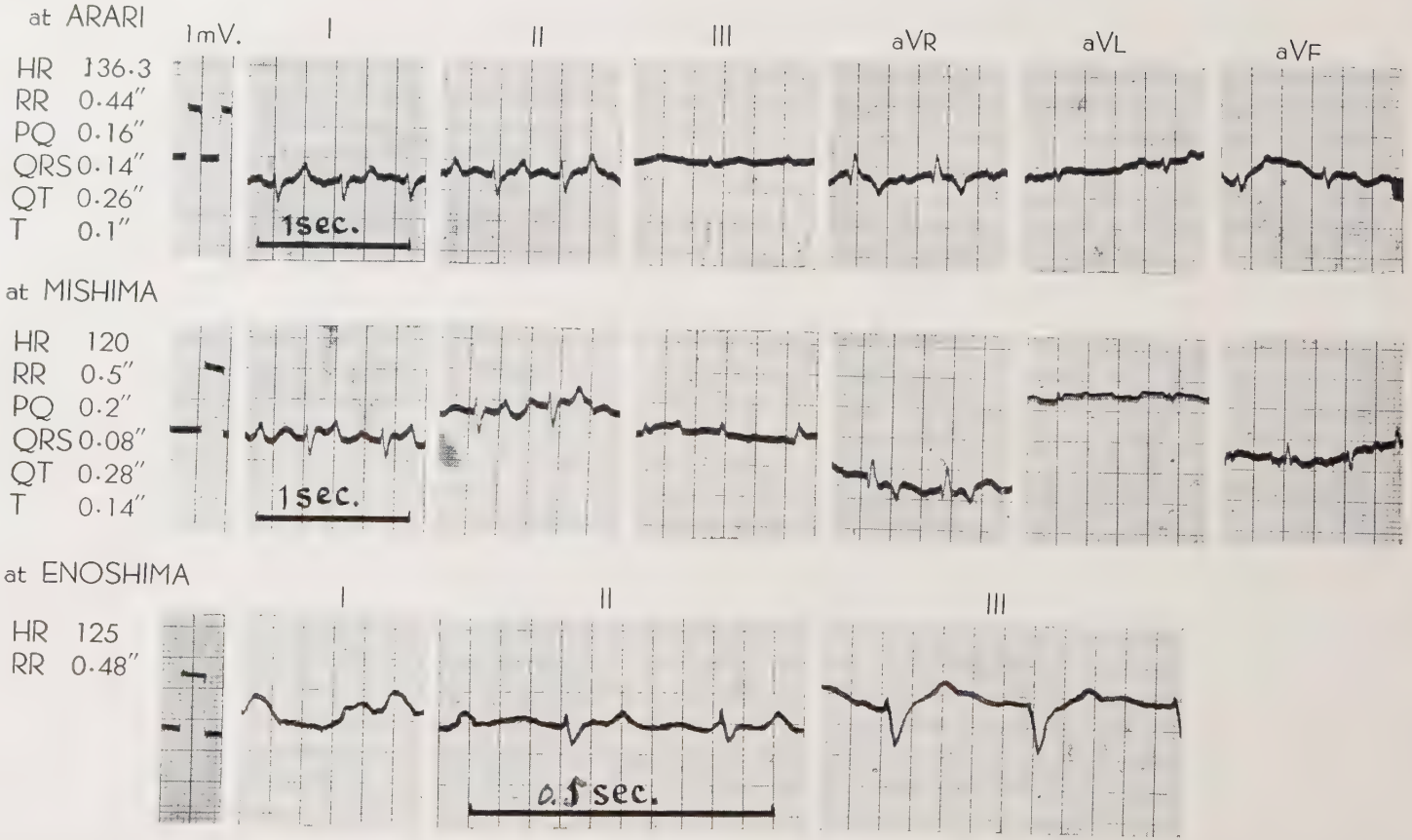


ECG

No. 5 Whale, July 18, 1957



metalplate-electrodes were attached to these spots without implanting.

## RESULTS

1) Heart-rate. The heart-rate of four Trusiops ranged 81 to 137 per minute and even after transportation, increasing in the course of time in two cases and decreasing in other two.

2) Details of ECG. Equal to other animals, the beats were regular except in the one which died, and *P*, *QRS* and *T* were observed. Proportions of *RR* to other parts did not differ from those of other animals. *T* was relatively low similar to a large animal such as elephant. In one case, *T* was normal at Arari, reversed at Mishima and recovered at Enoshima. In a second, *T* was normal at Arari, but reversed slightly at Mishima. But irrespective of these changes, they swam lively in Enoshima Aquarium and they are still alive. In the case which died, arrhythmia, markedly reversed *T* and disrupted *R* were observed.

3) Respiration. The rate was 1.5 to 4 per minute in the Aquarium in which they could swim voluntarily. But on the truck, it ranged 4 to 7 per minute and not regular during transportation.

## DISCUSSION AND SUMMARY

As described above, average heart-rate was 100 per minute. This was unexpectedly rapid. The first problem is whether this rate was normal or not. Although this record was done under unusual conditions, in other words, although aquatic animals were investigated on land under intensive stress, the heart-rate did not change markedly and details of ECG were not influenced exceedingly. From these results, it can be remarked that $\pm 20\%$ of this average would be the normal range of heart-rate for bottlenosed dolphin. The difference between that of adult and infant seemed small.

Low voltage of *T* is equal to that of a large animal such as elephant (for example, Indila in Ueno zoo, Tokyo). Reversal of *T* would be the sign of shock as is seen in human, because the one which died showed the sign of reversal in significant grade, but that of other cases was slight and might have recovered after they were released into the Aquarium.

Thanks are due to Dr. M. Nishiwaki and Staffs of Enoshima Aquarium who offered the authors the opportunity to investigate and the Fukuda ECG Co. who help them in the recording.

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昭和35年11月15日 印刷
昭和35年11月20日 発行

財団法人 日本捕鯨協会
編輯者 鯨類研究所
東京都中央区月島西河岸通12丁目4番地

編輯責任者 大村秀雄

印刷者 笠井康頼
東京都新宿区山吹町184番地

印刷所 株式会社 国際文献印刷社
東京都新宿区山吹町184番地

Printed at
Kokusai Bunken Insatsusha
Shinjuku-ku, Tokyo

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HONOLULU, HAWAII 96812